EXPRESS MAIL LABEL No. EL985160844US
PATENT APPLICATION
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GOLF COURSE ENVIRONMENTAL MANAGEMENT SYSTEM

Cross-Reference To Related Applications

[0001] This application claims priority to and the benefit of co-pending U.S. provisional patent application Serial No. 60/447,169, filed February 12, 2003, co-pending U.S. provisional patent application Serial No. 60/447,218, filed February 12, 2003, each of which applications is incorporated herein by reference in its entirety. This application is related to an application entitled "Battery-Powered Air Handling System For Subsurface Aeration," which application is being filed on even date herewith, and which is subject to assignment to the same assignee of the present application.

Field of the Invention

[0002] The invention relates to subsurface aeration systems in general and particularly to a subsurface aeration system servicing a plurality of areas of interest of a golf course.

Background of the Invention

[0003] In prior art systems for treating soil and turf by blowing and/or vacuuming through a duct network located underneath the turf, a low-pressure high-volume fan is typically used to move air into the soil profile or remove moisture from the soil profile. U.S. Pat. Nos. 5,433,759; 5,507,595; 5,542,208; 5,617,670; 5,596,836; and 5,636,473, the disclosure of each of which is incorporated herein by reference in its entirety, show different variations on equipment used for this purpose. Since a non-reversing fan always rotates in the same direction, changing the system from a blowing function to a vacuuming function requires disconnecting the duct network from the blowing outlet of the fan unit and connecting it to the vacuum inlet of the unit. In some variations, a 4-way valve is used to avoid the hassles involved with selectively connecting and disconnecting the duct network from the various ports of the fan unit. Manual operations limit the degree to which the process can be automated. In addition, considerable judgment is involved in knowing when to blow air into the duct network and when to remove air from the duct network by applying a

partial vacuum. Blowing air into the duct network when there is too much moisture in the soil profile can severely damage parts of the turf.

[0004] More recently, U.S. Patent No. 6,273,638, the disclosure of which is incorporated herein by reference in its entirety, disclosed additional features of an air handling system that includes an air handling device connectable to a duct network that is underneath a field having grass growing in it, at least one sensor disposed to measure a variable associated with the field, and a control unit connected to the air handling device to control operating parameters of the air handling device responsive to an output from the sensor. A heat exchanger is optionally part of the system. The variables associated with the field include temperature and moisture. The operating parameters of the air handling device include direction of the air flow, temperature of the air directed into the duct network, and the time of operation of the unit. The system optionally includes programmable control logic so that the sensor output automatically controls the operating parameters of the system. A computer with display is used to program the control logic, which can be done remotely over a modem or the internet. The sensor output can be viewed on the display to allow a user to manually control the operating parameters if desired.

[0005] What is lacking are systems that can be operated where power supplies have insufficient capacity, and systems that can handle a diversity of environmental parameters over disparate areas of interest.

Summary of the Invention

[0006] In one aspect, the invention relates to a system for managing a plurality of areas of interest within a golf course. The system comprises a plurality of electromechanical subsystems, each subsystem dedicated to a specific area of the golf course. Each subsystem comprises a subsurface aeration conduit for providing to the specific area of the golf course at least one of air under pressure and a partial vacuum; an air pump in fluid communication with the subsurface aeration conduit, the air pump configured to provide at least one of air under pressure and a partial vacuum; a motor mechanically connected to the air pump; a local control module responsive to a directive and to a datum, the local control module operatively

coupled to the motor; and at least one sensor that measures an environmental parameter, the at least one sensor in data communication with the local control module; and a programmable master control module in communication with each of the plurality of local control modules. The programmable master control module receives from at least two of the plurality of local control modules information representing a status of the respective specific area to which the local control module is dedicated, and in response to the information and to a command, the programmable master control module issues a directive to each of the local control modules to operate the electromechanical subsystem.

[0007] In one embodiment, the subsurface aeration conduit is a device used to supply air under pressure to or withdraw air under vacuum from the subsurface of the area of interest on the golf course. In one embodiment, the subsurface aeration conduit is a selected one of interconnecting perforated pipe, interconnecting porous pipe and channels formed by a placement of spacing devices. In one embodiment, the spacing devices comprise trays.

[0008] In one embodiment, the motor is an electric motor. In one embodiment, the programmable master control module is a selected one of a programmable computer, a programmable logic controller (PLC), and a programmable industrial controller. In one embodiment, the programmable master control module is in communication with a selected one of the plurality of local control modules by way of a selected one of a hard-wired communication link, a wireless communication link, and a fiber-optic communication link.

[0009] In one embodiment, the programmable master control module further comprises a connection to a communication network. In one embodiment, the communication network comprises a selected one of a telephone communication link, a wireless communication link, an optical communication link, and a packet-switched communication link.

[0010] In one embodiment, the system can communicate information over the selected communication link to a user at a remote location. In one embodiment, the system can receive a command over the selected communication link from a user at a remote location. In one embodiment, at least one of the local control modules further comprises a communication link accessible by way of a hand-held battery-powered device. In one

embodiment, the hand-held battery-powered device is a selected one of a cellular telephone, a personal digital assistant (PDA), and a pocket personal computer (pocket PC).

[0011] In one embodiment, at least one electromechanical subsystem further comprises a reversing mechanism in fluid communication with the air pump and with the subsurface aeration conduit, the reversing mechanism configured to cause air to flow in a first flow direction to provide air under pressure, and configured to cause air to flow in a second flow direction to provide a partial vacuum. In one embodiment, the reversing mechanism is responsive to the local control module.

[0012] In one embodiment, at least one electromechanical subsystem further comprises an irrigation system configured to irrigate at least a portion of a selected one of the specific areas of the golf course. In one embodiment, the local control module is operatively coupled to the irrigation system. In one embodiment, the irrigation system further comprises at least one sprinkler. In one embodiment, the irrigation system is configured to control a flow rate of water. In one embodiment, the irrigation system is configured to add substances to irrigation water. In one embodiment, the substances that the irrigation system is configured to add to irrigation water comprise at least one of a nutrient for a plant, an anti-fungal agent, and a chemical.

[0013] In one embodiment, the at least one sensor that measures an environmental parameter comprises a sensor that measures at least one of a temperature, a moisture content, an illumination, a chemical concentration, and a motion.

[0014] In one embodiment, the programmable master control module comprises a data recording and analysis module. In one embodiment, the data recording and analysis module is configured to record a selected one of a parameter relating to aeration, a parameter relating to irrigation, an operating parameter of an air pump, a temperature, a moisture content, a parameter relating to an additive applied to irrigation water, and a time. In one embodiment, the data recording and analysis module is configured to analyze one or more parameters relating to aeration, to irrigation, to operation of an air pump, to a temperature, to a moisture content, to an additive applied to irrigation water, and to a time. In one embodiment, the data recording and analysis module is configured to compare a selected

parameter to a setpoint. In one embodiment, the data recording and analysis module is configured to determine a status of at least one of the electromechanical subsystems.

[0015] In one embodiment, the programmable master control module further comprises a master display. In one embodiment, the master display exhibits a status of at least one of the electromechanical subsystems. In one embodiment, the status is a selected one of a time when the electromechanical subsystem begins to operate, a duration of operation of the electromechanical subsystem, an operating parameter of the electromechanical subsystem, a environmental condition, a fault condition, an alarm condition, a setpoint, and a directive. In one embodiment, the operating parameter of the electromechanical subsystem comprises a selected one of an electrical current, a pressure, a vacuum, a temperature, an air flow, and a water flow. In one embodiment, the environmental condition comprises a selected one of a soil temperature, an ambient temperature, a moisture content, an amount of solar radiation received in a specified time period, a soil salinity, and a detection of motion. In one embodiment, the ambient temperature is an ambient air temperature. In one embodiment, the moisture content is a selected one of a soil moisture content and an air humidity.

[0016] In one embodiment, the programmable master control module further comprises an input device for receiving commands from a user of the system. In one embodiment, the input device for receiving commands from a user of the system comprises a selected one of a keyboard, a key pad, a touch pad, a touch screen, a mouse, a joystick, a light pen, a pointing device, and a microphone. In one embodiment, the command is a command received from a user.

[0017] In one embodiment, the command is a command received from a computer program operating on the programmable master control module. In one embodiment, the temperature is a selected one of a soil temperature and an ambient temperature.

[0018] In one embodiment, at least one of the electromechanical subsystems further comprises a local display. In one embodiment, the local display exhibits a status of the electromechanical subsystem. In one embodiment, the status is a selected one of a time when the electromechanical subsystem begins to operate, a duration of operation of the

electromechanical subsystem, an operating parameter of the electromechanical subsystem, a environmental condition, a fault condition, an alarm condition, and a directive. In one embodiment, the operating parameter of the electromechanical subsystem comprises a selected one of an electrical current, a pressure, a vacuum, an air flow, and a water flow. In one embodiment, the environmental condition comprises a selected one of a soil temperature, an ambient temperature, a moisture content, an amount of solar radiation received in a specified time period, a soil salinity, and a detection of motion. In one embodiment, the ambient temperature is an ambient air temperature. In one embodiment, the moisture content is a selected one of a soil moisture content and an air humidity.

[0019] In one embodiment, the local control module is implemented as a virtual local control module on the programmable master control module.

[0020] In one embodiment, the areas of interest comprise at least a plurality of one or more golf greens, one or more fairways, one or more tee boxes, one or more walkways, one or more gallery viewing areas, one or more driving ranges, one or more putting greens, and one or more practice areas.

[0021] In another aspect, the invention features a method of extracting water from a specific area of interest selected from a plurality of areas of interest within a golf course. The method comprises the steps of providing a subsurface aeration system at each of the plurality of areas of interest, and operating the subsurface aeration system at the specific area of interest to provide at least a partial vacuum when the moisture reading exceeds a setpoint value, thereby extracting water from the specific area of interest. Each subsurface aeration system comprises a conduit for providing to the specific area of the golf course at least a partial vacuum; an air pump in fluid communication with the subsurface aeration conduit, the air pump configured to provide at least a partial vacuum; a motor mechanically connected to the air pump; and at least one sensor that provide a moisture reading of the area of interest.

[0022] In one embodiment, the method further comprises the steps of providing a control module responsive to a directive and to the moisture reading, the control module coupled to the subsurface aeration system to control the operation thereof; and causing the subsurface aeration system to operate to extract water in response to the directive and to a

determination that the moisture content exceeds the setpoint value.

[0023] In one embodiment, the method further comprises the steps of providing a programmable master control module in communication with the control module; receiving at the programmable master control module information sent from the control module, the information representing the moisture content; determining whether the moisture content exceeds the setpoint; and, if the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem.

[0024] In yet another aspect, the invention relates to a method of reducing a temperature of soil in a specific area of interest selected from a plurality of areas of interest within a golf course. The method comprises the steps of providing a subsurface aeration system at each of the plurality of areas of interest, and operating the subsurface aeration system to provide at least a partial vacuum when the ambient air temperature is lower than a first setpoint value, the soil temperature is higher than a second setpoint value, and the first setpoint value is less than the second setpoint value, thereby drawing ambient air through the specific area of interest to reduce a soil temperature thereof. Each subsurface aeration system comprises a subsurface aeration conduit for providing to the specific area of the golf course at least one of air under pressure and a partial vacuum; an air pump in fluid communication with the subsurface aeration conduit, the air pump configured to provide at least one of air under pressure and a partial vacuum; a motor mechanically connected to the air pump; at least one sensor that measures an ambient air temperature; and at least one sensor that measures a soil temperature.

[0025] In one embodiment, the at least one sensor that measures an ambient air temperature; and the at least one sensor that measures a soil temperature are a unitary structure.

[0026] In one embodiment, the method further comprises the steps of providing a control module responsive to a directive, to the ambient air temperature, and to the soil temperature, the control module coupled to the subsurface aeration system to control the operation thereof; determining whether the ambient air temperature is lower than a first

setpoint value, the soil temperature is higher than a second setpoint value, and the first setpoint value is less than the second setpoint value; and, if the determination is positive, causing the local control module to operate the subsurface aeration system to reducing a temperature of soil. In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, directing the local control module to operate the subsurface aeration system to reduce a temperature of soil.

[0027] In one embodiment, the method further comprises the steps of providing a programmable master control module in communication with the control module; receiving at the programmable master control module information sent from the control module, the information representing the ambient air temperature and the soil temperature; determining whether the ambient air temperature is lower than a first setpoint value, the soil temperature is higher than a second setpoint value, and the first setpoint value is less than the second setpoint value; and, if the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem to reduce a temperature of soil.

[0028] In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem to reduce a temperature of soil.

[0029] In yet a further aspect, the invention features a method of reducing a temperature of soil in a specific area of interest selected from a plurality of areas of interest within a golf course. The method comprises the steps of providing a subsurface aeration system at each of the plurality of areas of interest, and operating the subsurface aeration system to provide air under pressure when the ambient air temperature is higher than a first setpoint value, the soil temperature is higher than a second setpoint value, the first setpoint value is higher than the second setpoint value, and the soil moisture content is less than a third setpoint value, thereby pushing air under pressure through the specific area of interest to reduce a soil temperature thereof. Each subsurface aeration system comprises a subsurface aeration conduit for providing to the specific area of the golf course at least one of air under

pressure and a partial vacuum; an air pump in fluid communication with the subsurface aeration conduit, the air pump configured to provide at least one of air under pressure and a partial vacuum; a motor mechanically connected to the air pump; at least one sensor that measures an ambient air temperature; at least one sensor that measures a soil temperature; and at least one sensor that measures a soil moisture content.

[0030] In one embodiment, at least two of the at least one sensor that measures an ambient air temperature, the at least one sensor that measures a soil temperature, and the at least one sensor that measures a soil moisture content are a unitary structure. In one embodiment, the method further comprises the steps of providing a control module responsive to a directive, to the ambient air temperature, to the soil temperature, and to the soil moisture content, the control module coupled to the subsurface aeration system to control the operation thereof; determining whether the ambient air temperature is higher than a first setpoint value, the soil temperature is higher than a second setpoint value, the first setpoint value is higher than the second setpoint value, and the soil moisture content is less than a third setpoint value; and, if the determination is positive, causing the subsurface aeration system to operate to reducing a temperature of soil.

[0031] In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, directing the local control module to operate the subsurface aeration system to reduce a temperature of soil.

[0032] In one embodiment, the method further comprises the steps of providing a programmable master control module in communication with the control module; receiving at the programmable master control module information sent from the control module, the information representing the ambient air temperature, the soil temperature and the soil moisture content; determining whether the ambient air temperature is higher than a first setpoint value, the soil temperature is higher than a second setpoint value, the first setpoint value is higher than the second setpoint value, and the soil moisture content is less than a third setpoint value; and, if the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem to reduce a temperature of soil.

[0033] In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem to reduce a temperature of soil. In one embodiment, the air under pressure is ambient air that has been cooled by passing through at least a portion of the subsurface aeration conduit configured as a heat exchanger in contact with subsurface soil.

[0034] In still another aspect, the invention relates to a method of reducing a temperature of soil in a specific area of interest selected from a plurality of areas of interest within a golf course. The method comprises the steps of providing a subsurface aeration system at each of the plurality of areas of interest, and operating the subsurface aeration system to provide air under pressure when the ambient air temperature is lower than a first setpoint value, the soil temperature is higher than a second setpoint value, the first setpoint value is lower than the second setpoint value, and the soil moisture content is less than a third setpoint value, thereby pushing air under pressure through the specific area of interest to reduce a soil temperature thereof. Each subsurface aeration system comprises a subsurface aeration conduit for providing to the specific area of the golf course at least one of air under pressure and a partial vacuum; an air pump in fluid communication with the subsurface aeration conduit, the air pump configured to provide at least one of air under pressure and a partial vacuum; a motor mechanically connected to the air pump; at least one sensor that measures an ambient air temperature; at least one sensor that measures a soil temperature; and at least one sensor that measures a soil moisture content.

[0035] In a further aspect, the invention features a method of increasing a temperature of soil in a specific area of interest selected from a plurality of areas of interest within a golf course. The method comprises the steps of providing a subsurface aeration system at each of the plurality of areas of interest, and operating the subsurface aeration system to provide air under pressure when the ambient air temperature is greater than a first setpoint value, the soil temperature is less than a second setpoint value, the first setpoint value is higher than the second setpoint value, and the soil moisture content is less than a third setpoint value, thereby pushing ambient air through the specific area of interest to increase a soil temperature thereof.

Each subsurface aeration system comprises a subsurface aeration conduit for providing to the specific area of the golf course at least one of air under pressure and a partial vacuum; an air pump in fluid communication with the subsurface aeration conduit, the air pump configured to provide at least one of air under pressure and a partial vacuum; a motor mechanically connected to the air pump; at least one sensor that measures an ambient air temperature; at least one sensor that measures a soil temperature; and at least one sensor that measures a soil moisture content.

[0036] In one embodiment, at least two of the at least one sensor that measures an ambient air temperature, the at least one sensor that measures a soil temperature, and the at least one sensor that measures a soil moisture content are a unitary structure. In one embodiment, the method further comprises the steps of providing a control module responsive to a directive, to the ambient air temperature, to the soil temperature, and to the soil moisture content, the control module coupled to the subsurface aeration system to control the operation thereof; determining whether the ambient air temperature is greater than a first setpoint value, the soil temperature is less than a second setpoint value, the first setpoint value is higher than the second setpoint value, and the soil moisture content is less than a third setpoint value; and, if the determination is positive, causing the subsurface aeration system to operate to increase a temperature of soil.

[0037] In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, directing the local control module to operate the subsurface aeration system to increase a temperature of soil.

[0038] In one embodiment, the method further comprises the steps of providing a programmable master control module in communication with the control module; receiving at the programmable master control module information sent from the control module, the information representing the ambient air temperature, the soil temperature and the soil moisture content; determining whether the ambient air temperature is greater than a first setpoint value, the soil temperature is less than a second setpoint value, the first setpoint value is higher than the second setpoint value, and the soil moisture content is less than a third setpoint value; and, if the determination is positive, issuing from the programmable master

control module the directive to the local control module to operate the electromechanical subsystem to increase a temperature of soil.

[0039] In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem to increase a temperature of soil.

[0040] In a still further aspect, the invention relates to a method of increasing a temperature of soil in a specific area of interest selected from a plurality of areas of interest within a golf course. The method comprises the steps of providing a subsurface aeration system at each of the plurality of areas of interest, and operating the subsurface aeration system to provide at least a partial vacuum when the ambient air temperature is greater than a first setpoint value, the soil temperature is lower than a second setpoint value, and the first setpoint value is higher than the second setpoint value, thereby drawing ambient air through the specific area of interest to increase a soil temperature thereof. Each subsurface aeration system comprises a subsurface aeration conduit for providing to the specific area of the golf course at least one of air under pressure and a partial vacuum; an air pump in fluid communication with the subsurface aeration conduit, the air pump configured to provide at least one of air under pressure and a partial vacuum; a motor mechanically connected to the air pump; at least one sensor that measures an ambient air temperature; and at least one sensor that measures a soil temperature.

[0041] In one embodiment, the at least one sensor that measures an ambient air temperature and the at least one sensor that measures a soil temperature are a unitary structure.

[0042] In one embodiment, the method further comprises the steps of providing a control module responsive to a directive, to the ambient air temperature, and to the soil temperature, the control module coupled to the subsurface aeration system to control the operation thereof; determining whether the ambient air temperature is greater than a first setpoint value, the soil temperature is lower than a second setpoint value, and the first setpoint value is higher than the second setpoint value; and, if the determination is positive,

causing the subsurface aeration system to operate to increase a temperature of soil.

[0043] In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, directing the local control module to operate the subsurface aeration system to increase a temperature of soil.

[0044] In one embodiment, the method further comprises the steps of providing a programmable master control module in communication with the control module; receiving at the programmable master control module information sent from the control module, the information representing the ambient air temperature and the soil temperature; determining whether the ambient air temperature is greater than a first setpoint value, the soil temperature is lower than a second setpoint value, and the first setpoint value is higher than the second setpoint value; and, if the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem to increase a temperature of soil.

[0045] In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem to increase a temperature of soil.

[0046] The foregoing and other objects, aspects, features, and advantages of the invention will become more apparent from the following description and from the claims.

Brief Description of the Drawings

[0047] The objects and features of the invention can be better understood with reference to the drawings described below, and the claims. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the drawings, like numerals are used to indicate like parts throughout the various views.

[0048] FIG. 1 is a side elevation in section showing a prior art apparatus for heating or cooling a golf course green;

[0049] FIG. 2 is a perspective view in partial section showing a prior art heating and

cooling system for a golf course green comprising a horizontally disposed ground source heat exchanger and an auxiliary blower;

[0050] FIG. 3 is a further embodiment of the prior art heating and cooling system for a golf course green comprising a vertically disposed ground source heat exchanger;

[0051] FIG. 4 is a further embodiment of the prior art heating and cooling system having an alternate ground source circuit for cooling a golf green and a multiple circuit heat exchanger;

[0052] FIG. 5 is a still further embodiment of the prior art heating and cooling system wherein the system is able to nourish the turf and soil of a golf course green;

[0053] FIGS. 6 and 7 show prior art apparatus for reversing the flow of air moving through a treatment system for a golf course green;

[0054] FIG. 8 is a plan view showing prior art apparatus for selectively heating or cooling the turf of a grass-covered area;

[0055] FIG. 9 is an enlarged side elevation showing a prior art water separator and holding tank utilized in a treatment system for a golf course green;

[0056] FIG. 10 illustrates a prior art system for treating a golf green wherein the blower, a four-way reversing unit and the moisture separator are all mounted upon a self-propelled vehicle;

[0057] FIG. 11 is a side elevation in section showing a prior art system for treating golf course greens;

[0058] FIG. 12 is a perspective view of the prior art system shown in FIG. 11;

[0059] FIG. 13 is a high level block diagram of a storage battery system embodying principles of the invention;

[0060] FIG. 13A is a high level block diagram illustrating an embodiment of a battery, a controller, a motor, and a blower, according to principles of the invention;

[0061] FIG. 14 is a high level block diagram of a second storage battery system embodying principles of the invention;

[0062] FIG. 15 is a graph of the observed values for electric current and for back pressure as a function of air flow delivered, according to principles of the invention;

[0063] FIG. 16 is a graph of the calculated results for electric power consumed, power transmitted to drive the flowing air, and the efficiency of the fan as a function of air flow delivered, according to principles of the invention;

[0064] FIG. 17 is a schematic diagram showing a test circuit for a DC motor driven by a 48 volt battery, according to principles of the invention;

[0065] FIG. 18 is a schematic diagram of a motor-blower assembly useful in practicing the invention;

[0066] FIG. 19 is a plan diagram of a motor-blower, a battery and a conduit situated with a chamber, according to principles of the invention;

[0067] FIG. 20 is a plan diagram that shows an arrangement of components employed in testing the noise level generated during the operation of a system built according to the principles of the invention;

[0068] FIG. 21 shows a schematic view of a prior art reversing shuttle for use in an air handling device;

[0069] FIG. 22 shows a schematic view of the prior art reversing shuttle of FIG. 21 used to explain the operation thereof;

[0070] FIG. 23 shows a schematic view of the prior art air handling device as part of the larger prior art air handling system;

[0071] FIG. 24 shows a schematic view of an embodiment of an air handling system known in the prior art;

[0072] FIG. 25 is a drawing showing a plurality of electromechanical subsystems, each subsystem dedicated to a specific area of a golf course, and communicating with a programmable master control module, according to principles of the invention;

[0073] FIGS. 26-29 are drawings depicting exemplary embodiments of a local control module with different features, according to principles of the invention;

[0074] FIG. 30 is a drawing showing an exemplary embodiment of a user display, according to principles of the invention;

[0075] FIG. 31 is a diagram of an exemplary local control module, showing various control signal paths, according to principles of the invention;

[0076] FIG. 32 is a diagram of an illustrative communication configuration including a local control module and a programmable master control module, and showing various environmental sensor signal paths, according to principles of the invention;

[0077] FIG. 33 is a diagram showing an exemplary configuration of communication paths including remote access via the Internet, according to principles of the invention; and

[0078] FIG. 34 is an enumeration of some of the components, communication and control channels, and logic structure of one or more embodiments of the golf course environmental management system, according to principles of the invention.

Detailed Description of the Invention

[0079] In one embodiment, the systems according to principles of the invention are useful in operating subsurface aeration systems in locations where there is insufficient power provided by conventional grid-connected power supplies. In another embodiment, the systems according to principles of the invention are useful in managing the provision of such aeration services to a plurality of locations, for example areas having different requirements from one another.

[0080] As will be explained in greater detail hereinbelow, an example that illustrates the above advantages and solutions in the provision of subsurface aeration and associated services is discussed with reference to a golf course that has a plurality of greens or other areas of interest having different requirements. Different areas on a golf course can have differences in many features, such as in topography, in elevation, in exposure to the sun, and in other features such as water table level, or being subject to wind. For example, a first green is surrounded by a water hazard (for example, a green situated on an island surrounded by water and accessible by a footbridge or golf cart path); a second green is surrounded by sand traps; a third green is exposed to full sun for much or all of a day; and a fourth green is surrounded by trees that shade the green from direct sunlight for a considerable part of the day. Different greens may have different soil conditions and/or different elevations, some may be sloped or terraced; and some may be subject to other unique conditions, such as prevailing winds, or exposure to salt water or salt spray (for example a course situated at the

ocean). Some greens or other areas of interest may be situated in areas where the power source that is available (such as a 110 Volt AC power line of modest capacity) is not sufficient to directly supply the electricity needed to operate the electromechanical systems that are needed.

[0081] A benefit that the systems of the invention provide includes the ability to provide subsurface aeration services even when a power source, such as an AC power line, that provides only insufficient capacity is present. Other benefits that the systems of the invention provide include the ability to manage the plurality of areas of interest from a central location, for example a club house; to automate the management functions; to allow monitoring of conditions at an area of interest or the status of an electromechanical system associated with an area of interest; to allow a user of the systems to assert local control when at the area of interest, as necessary; and to allow a user situated at an off-site location to access the systems, review the status, make determinations as to the appropriate actions to be taken, and as needed, institute and/or monitor control actions.

[0082] Turning to FIG. 1, there is shown a prior art system for heating or cooling a golf course green generally referenced 10. Although the present invention will be explained in detail with reference to the treatment of the turf and subsoil of a golf green, it should be clear that the present invention has wider application and can be used in any type of similar application. Outdoor sports stadiums having grass playing fields are examples of sites where subsurface soil treatment is desirable. Brooder houses for various types of poultry is a still further application where underground soil treatment is highly desirable in maintaining the health of the housed poultry.

[0083] The green depicted in FIG. 1 is one that has been constructed in compliance with the specifications of the United States Golf Association (USGA). The green includes a top layer 11 that supports a grass turf 12. The top layer is about twelve inches deep and contains a mix that is 80% fine sand and 20% organic matter which is typically peat moss. Immediately below the top layer is an intermediate layer 13 that is about two to four inches deep and contains choker sand. Finally, a lower layer 14 of pea gravel about four inches deep is placed directly below choker sand layer.

[0084] Typically, buried in the subsoil of the green is a duct network that is in communication with the lower level gravel bed and serves to carry excess water in the subsoil region away from the green. The duct network includes one or more main feeder lines 15 that are interconnected to a series of distribution lines 16--16. In the embodiment shown, the lines are arranged in a herringbone pattern that encompasses the green area. In another embodiment, the lines can be arranged as a series of parallel pipes connected along a common border or edge. The lines have openings that permit excess moisture in the soil to be collected in the lines. The lines are laid in the ground so that the collected moisture is gravity fed to the drainage system servicing the golf course. As will be explained in greater detail below, existing duct network can be easily retrofitted to the present system to provide underground heating, cooling and other beneficial treatment to the subsoil and turf of the green.

[0085] As shown in FIG. 1, the main feeder lines 15 of the present system are connected to a supply line 17 which, in turn, is connected to the outlet side of a blower or an air pump 19. A portion of the supply line, shown in FIG. 1 as a linear section, is buried below the surface of the ground at a depth wherein the ground temperature is relatively constant and not readily responsive to changes in ambient air temperature, for example at a depth of between four and ten feet.

[0086] The length of the linear section is such that sufficient energy is exchanged between the ground and the air moving through the line to bring the air temperature close to the ground temperature. The linear section of the line thus acts as a ground source heat pump to either heat or cool the air moving through the line, depending upon the temperature of ambient air drawn into the blower as compared to the ground temperature. In one embodiment, warm air under pressure is cooled from the initial ambient air temperature by virtue of conductive heat transfer to the subsurface aeration conduit and subsurface media (sand, soil, gravel, stone) when the conduit and the media are at a lower temperature than the ambient air temperature. The cooled air moves through the soil at the area of interest and reduces this soil temperature by virtue of conductive heat transfer.

[0087] The blower can be located some distance from the green either above or below

ground and is insulated against noise which might distract golfers playing the course. The blower is adapted to draw in ambient air and deliver it through the lines to the duct network under the green. The air is pumped at relatively low pressure and at a high volume to prevent undue heating of the air and is distributed into the subsoil by means of openings or nozzles formed in the duct lines. The air is thus forced upward through the soil to provide either heating or cooling of both the soil and the turf.

[0088] In the event the ambient air temperature is relatively high, and the soil temperature surrounding and just below the turf is relatively high, the air will be cooled as it moves through the heat exchanger section of the system thus providing cooling to the turf area or area of interest. If the ambient air temperature is relatively low, and the soil temperature surrounding and just below the turf is relatively low, the air moving through the system will be warmed by the ground effect thus providing heating to the turf area.

[0089] An early example of the system involved a prototype system that was built and tested which proved that air moving through a system of the type herein described could be pushed upward through the subsoil profile of a green constructed in accordance with USGA specifications. An air tight housing five feet long, three feet wide and two feet nine inches deep was constructed and a four inch diameter feeder line was seated in the bottom of the housing. One end of the feeder line was blocked and the other attached to a blower. The feeder line was a typical drain pipe used in association with most existing greens. The line was covered with pea gravel and the gravel layer brought to about four inches over the top of the pipe. A three-and-one-half inch layer of choker sand was placed over the pea gravel and the choker sand covered with a twelve inch layer of an 80-20 USGA mix. The edge region between the walls of the housing and the layers of material were sealed to prevent air from flowing along the housing walls. The subsoil profile was watered and compacted.

[0090] The blower (New York Blower Model No. 1406A-3) was driven by a three horsepower Lesson motor (Cat. No. 13126300) and was attached to the four inch feeder line that was in communication with the subsoil profile by means of a four to six inch supply line. The top of the housing was closed by a cover frame surrounding a plastic film. The edges of the cover frame were then sealed. While the blower motor is described in the embodiments

presented herein as an electric motor, those of ordinary skill will understand that other sources of motive power for driving the blower can be substituted for the electric motor.

[0091] The blower motor was started and ambient air discharged by the blower was metered into the four inch feeder line by opening a control valve in the supply line. Perched water that collected in the subsoil was observed through a window in the housing. The plastic film in the sealed cover became inflated clearly indicating that air from the blower was flowing freely through the subsoil profile. A fragrance was sprayed into the ambient air being drawn into the pump. The fragrance was clearly detected at the top of the soil profile and on the plastic film. Removal of the block in the end of feeder line further showed that positive pressure air was moving through the line. Visual observations of the perched water showed that water did not impede the flow of air through the soil profile.

[0092] Temperature measurements of the subsoil were also taken during the test. Ambient air temperature was 38 degrees F. The initial choker sand temperature was 45 degrees F and the USGA mix temperature was 41 degrees F at the mid depth level. After a short operating time, the temperature of the choker sand and the USGA mix equalized at about 40 degrees F showing that the soil profile was being cooled by the ambient air moving through the system. The test was repeated showing similar results.

[0093] FIG. 2 illustrates another embodiment of the prior art wherein like numbers depict like elements as those described in reference to FIG. 1. Here again, air from a blower 19 is delivered to the feeder and distributing line 15 and 16 situated beneath the green by means of a supply line 17. In this embodiment, a flat horizontally disposed heat exchanger coil 20 is connected between the supply line 17 and the blower discharge. The coil is again buried at least four feet below ground level and provides a sufficient heat transfer surface so that the temperature of the air moving through the line will approach that of the earth surrounding the line. In this embodiment, an auxiliary blower 22 is connected into the supply line downstream from the heat exchanger coil and serves to help push the treated air through the supply line. The auxiliary blower 22 preferably is situated below ground to minimize heat loss and to suppress blower noise.

[0094] FIG. 3 illustrates a further embodiment of the prior art wherein a vertically

disposed heat exchanger 25 is operatively connected between the supply line 17 and the discharge side of the blower 19. The heat exchanger is a U-shaped line that is sunk to a depth well below that of the supply line into cooler regions of the earth for more efficient heat transfer. A four-way reversing valve unit 27 for reversing the flow of air through the system is positioned between the discharge line 28 of the blower 19 and the heat exchanger.

[0095] As illustrated in FIGS. 6 and 7, the reversing valve unit 27 contains four control valves 30-33 that are mounted in a bridge configuration. The entrance to the bridge is connected into the discharge line 28 of the blower 19. One pair of the bridge legs are connected to the heat exchanger 25 while the opposing pair of legs are connected to ambient air inlet by line 35. The exit to the bridge is connected to a return line 29 connected to the blower inlet. FIG. 6 depicts the valve positioning when the blower 19 is providing cooling or heated air to the duct network under the turf. At this time valves 30 and 32 are closed and valves 31 and 33 are opened. Ambient air is delivered to the blower via the air inlet line 35 and the blower air discharge is pushed through the heat exchanger 25 and the duct network.

[0096] Reversing the valve positions as shown in FIG. 7 places the inlet of the four way valve 27 in communication with the heating and cooling system and its discharge 35 in communication with ambient air. This in turn causes the blower 19 to draw ambient air downwardly through the green soil profile. Any excess moisture or water in the subsoil is thus pulled into the duct network beneath the green. As shown in FIG. 3, the network is arranged to drain into a sump 37 via a drain line 38 from which it is exhausted into the main drainage system servicing the golf course. A valve 40 is mounted in the drain line 38. The valve is closed when air is being pushed from the blower 19 through the soil profile and opened when the blower operation is reversed, that is when the blower 19 is providing a partial vacuum at line 17 so as to pull ambient air through he soil and into the duct network. The arrows in FIG. 3 indicate the direction of flow of pressurized air provided by the blower 19 when the four way valve 27 is configured as shown in FIG. 6. When the four way valve 27 is configured as shown in FIG. 7, the flow direction of air is opposite to the direction of the arrows in FIG. 3.

[0097] In an alternative embodiment depicted in FIG. 4, the outlet of blower 19 is

connected to a multiple circuit heat exchanger 40. Each circuit 42--42 is a vertically disposed double helix line with the circuits being buried about ten feet below ground level. The circuits are connected in parallel flow relationship and each circuit is connected to a condensate drain sump 45. The outlet of the exchanger is coupled to the under green duct network via supply line 17 to provide heating or cooling to the soil profile.

[0098] In some embodiments, irrigation is provided for an area of interest on a golf course, such as on a golf green. An auxiliary pipe line 47 surrounds the periphery of the green and includes a series of spaced apart pop-up heads or sprinklers 50--50 of the type typically used around golf courses for distributing water above ground. The auxiliary line sprinklers are attached to the normal irrigation supply line (not shown in FIG. 4) by a one-quarter inch fluid line 49 servicing the course. The heads are designed to be elevated by the air pressure and distribute water mist over the green surface.

[0099] A valve 53 is provided in the fluid line 49 that is operable to isolate the auxiliary pipe line 47 from the normal irrigation line. The auxiliary pipe line 47 is coupled to the blower supply line 17 by a shunt line 55. A valve 56 is mounted in the shunt line and a second valve 57 is similarly mounted in the supply line downstream from the shunt line. The valves 56 and 57 can be cycled to deliver air from the blower to the pop-up heads 50 which can be modified to also distribute air as well as water over the surface of the green. Valve 53 can be opened at this time to supply both water and air to the heads 50. This, in turn, causes a fine mist to cover the green surface thus providing for more effective green cooling. A drain system 58 is tied into the under green duct network and functions as explained above to carry away excess moisture collected in the duct network.

[0100] FIG. 5 illustrates another embodiment of a heating and cooling system that is similar to that described with reference to FIG. 1. Here again, the blower 19 pushes air through the supply line 17 into the under green duct network whereupon the air is forced upwardly through the soil profile. A pressurized tank 60 is mounted adjacent to the green and is connected into the supply line by means of a delivery line 61. A metering valve 62 is mounted in the delivery line. The tank may be used to store either gaseous or fluid materials for feeding or fortifying the soil or doing away with unwanted pests, disease conditions, or

plant or animal parasites that are harmful, and thus promote the growth and/or health of the grass. Examples of such materials are chemicals, nutrients, micro-organisms, and any other matter that can be introduced into a flowing air stream to treat turf. Opening the metering valve introduces the material into the air flow which, in turn, carries it upwardly through the subsoil profile where it is efficiently distributed and absorbed into the soil.

[0101] FIG. 8 shows another embodiment of the prior art for treating a grass-covered area such as a golf course green which is generally referenced 10.

[0102] The green depicted in FIG. 8 is constructed in compliance with specifications issued by the United States Golf Association (USGA). The green includes a top layer of soil 11 that is about 12 inches deep for supporting a grass playing surface or turf 12. Immediately below the soil layer 11 is a layer of choker sand 13 that is about 2-4 inches deep. The choker layer is supported upon a gravel bed 14 that is at least 4 inches deep. The gravel bed contains particles of a size and shape such that interstices are formed between the particles thus allowing air to freely circulate throughout the bed beneath the soil profile of the green.

[0103] A duct network of perforated pipes is laid within the gravel bed and is connected to a blower 19 capable of moving air in both directions through the gravel bed 14 at a volume and pressure such that air is either pumped upwardly or drawn downwardly through the soil profile. The network includes a main feeder line 15 which is coupled to a series of distribution lines 16--16 in a herringbone configuration that conforms to the general shape of the green. In some embodiments, the pipes have an inside diameter of between 4 to 6 inches and the lines are typically spaced about 10-15 feet apart to maintain thorough air distribution throughout the bed. The pipes in the duct network slope downwardly towards a control valve 819 that can be cycled manually or automatically to selectively connect the duct network via line 820 to a drain system servicing the golf course or, alternatively, to a separator unit 821 via line 822. A check valve 824 is connected into the drain line below the tee 825. The opposite end of the duct network contains a service valve 823 that may be connected to a water supply to periodically flush the pipelines when required.

[0104] A blower 19 is connected to the separator unit by means of a four way flow reversing unit 831 that permits air to be either drawn out of or pushed into the pipe line

network. The four way flow reversing unit 831 is equivalent to the four way reversing unit 27 described hereinabove with respect to FIGS. 6 and 7.

[0105] FIG. 6 depicts the positioning of the flow reversing unit valves when air is being pumped into the duct network. A predetermined volume of air is delivered under pressure through the pipe line into the gravel bed 14 so that the air is distributed uniformly throughout the bed and then driven upwardly to penetrate the entire soil profile. The flow of air through the soil is employed to either heat or cool the turf, depending on the prevailing ambient and ground conditions. The flow of air through the soil also provides an added benefit in that it serves to aerate the soil and thus promotes the health and growth of the grass turf. During the pumping operational mode, valves 30 and 32 are closed and valves 31 and 33 are opened.

[0106] To reverse the function of the blower 19 the valves are cycled as shown in FIG. 7 to open valves 30 and 32 and close valves 31 and 34. Reversal of the valve positions functions to connect the suction side of the blower with pipe lines in the duct network. Sufficient suction or partial vacuum is provided by the blower 19 to draw ambient air downwardly through the soil profile into the gravel distribution bed 14 to again provide the desired heating or cooling of the grass turf. A further benefit of the suction mode of operation is that it affords rapid removal of excess water from the soil profile during periods of heavy rain or flooding. Excess water in the soil is drawn quickly down into the gravel bed 14 and collected in the pipe lines. As will be explained in greater detail below, the moisture laden air stream is drawn into the separator unit 821 where the moisture and any airborne particulates are removed from the air stream and delivered to a holding tank 860 without interrupting the operation of blower 19. The present apparatus can, in addition, continuously collect and drain moisture when operating in the pumping or suction mode. Alternatively, the blower operation may be terminated for a short period of time during which valve 819 is cycled allowing any water collected in the duct lines to be gravity fed to the drain system, where the water can flow past check valve 824 and away from the green or other area of interest.

[0107] FIG. 9 illustrates schematically the construction of the separator unit 821 which includes a tank 845 that is connected to the reversing unit 831 via line 839. The tank is

similarly connected to the control valve 819 of FIG. 8 via line 822. Normally when the blower 19 is operating, the control valve 819 is cycled to place the separator unit in communication with the duct network beneath the area of interest. A cover 846 is attached to the top of the tank and is closed against the tank using suitable fasteners, or if the cover is heavy enough, using the force of gravity. A seal 847 is mounted between the cover and the tank body to render the unit air tight. A baffle 849 is hung from the cover so that it is in the air stream moving through the separator. The baffle contains a filter 850 that is adapted to separate moisture and particulate materials contained in the air stream and deposit them at the bottom of the tank 845.

[0108] A drain line 851 is connected into the bottom wall 852 of the tank 845. A U-shaped trap 853 is connected into the drain line 851. The trap contains a first vertical leg 854 that collects water from the bottom of the separator tank and a second shorter vertical leg 855 that is connected to the first leg by a 180 degree bend 857. A flush line 858 is connected into the bend and contains a control valve 859 that can be cycled automatically or manually to flush the trap 853 when the trap 853 requires cleaning. The shorter leg 855 of the trap 853 is connected to a holding tank 860 (see FIG. 8) via line 861. A second control valve 862 is connected into line 861 which again can be cycled manually or automatically to open and close the holding tank line 861.

[0109] The water head pressure contained in the trap 853 is greater than the pumping or suction pressure of the blower 19. Any water collected in the bottom of the separator tank can thus be continually passed through the trap without adversely effecting or interrupting the operation of the blower 19.

[0110] A water level sensor 863 is mounted in the leg 854 of the trap and is arranged to send a low water level signal to a controller 864 when the water in the trap is reduced to a predetermined level. Normally when the blower 19 is operating in a suction or partial vacuum mode, ground water or moisture is being collected in the separator tank 845 and the trap 853 will remain full. However, during times when the blower 19 is in a pumping mode, the moisture in the separator tank can be evaporated into the air stream and thus removed from the tank requiring periodic addition of water to the tank. When the sensor detects a low

water level in the trap, the controller will automatically open control valve 865 in water supply line 866 whereupon water from supply reservoir 867 is delivered into the tank to bring the water in the trap 853 back up to the desired operating level.

[0111] Water collected in the holding tank can be either disposed of in an environmentally safe manner or alternatively, redistributed over the grass playing field to nourish the turf, particularly during periods of less than normal rainfall. As shown in FIG. 8, a liquid pump 869 is connected to the holding tank 860 and provides liquid from the tank under pressure to a hose 870. The hose is equipped with a nozzle 871 for either distributing water over the playing field, or delivering the liquid to a suitable disposal unit (not shown). In an alternative embodiment, provided that suitable precautions are taken to avoid contaminating a potable water system, the water held in the holding tank 860 can be applied to the area of interest using an irrigation system such as that shown in FIG. 4 and described above.

[0112] FIG. 10 illustrates a prior art system wherein some of the system components are mounted on a mobile transporter unit so that they can be easily transported from one area of interest such as a golf green or playing field to another. In the case of a golf course that has a number of putting greens, each of which has its own duct network, the ability to transport much of the soil treatment equipment from one green to another as needed represents a considerable saving in equipment cost.

[0113] In this embodiment, the mobile transporter is a self-propelled vehicle 878 having a flat bed 877 upon which the mobile equipment includes blower 830, flow reversing unit 831, separator unit 821, holding tank 860 and a liquid pump (not shown). The mobile equipment components are all connected as described above and function as previously noted. The service line 822 in this case is a flexible line having a quick disconnect 880 at its distal end. The quick disconnect is arranged to be releasably connected to a mating coupling located on the separator side of control valve 819.

[0114] Normally, the control valve is cycled to permit the duct network to gravity feed directly into drain line 820 when the mobile unit is disconnected from the duct network. Valve 819 is recycled when the mobile equipment is coupled thereto, thus placing the mobile

equipment in communication with the duct network whereupon air can be selectively moved in either direction through the soil profile of the area of interest, such as a golf green or playing field.

[0115] FIGS. 11 and 12 show a golf course green generally referenced 10 that has been constructed in accordance with USGA specifications. The description given for FIG. 1 above applies with regard to FIGS. 11 and 12 as well.

[0116] As best seen in the perspective view of FIG. 12, a drain system that includes a duct network generally referenced 18 is buried beneath the gravel bed 14. The network includes a central distribution line 15 from which a series of feeder lines or distribution lines 16--16 extend to service the area of the greens. The lines 16 are perforated and are placed in communication with the gravel bed so that any excess moisture in the bed is collected in the lines. The lines are laid in the ground so that the collected moisture is gravity fed into a drain line 1120 which, in turn, carries the moisture to the main drainage system (not shown) servicing the golf course. In some embodiments, a clean out line 1122 is located at the upper end of the distribution line 15 that permits the duct network to be flushed using high pressure water. A shut-off valve 1125 is operatively connected into the clean out line for closing off the upper end of the duct network (1122). In an alternative embodiment, the clean out line 1122 is simply capped to seal off the flushout, and the cap is removed when a flushing operation is performed.

[0117] The lower end of the distributor line is equipped with a two-way valve 1130 having a disconnect fitting 1131 at one end of the valve outlet. The other outlet of the valve 1130 is connected to drain line 1120. Downstream from the connection is a shut off valve 1133 mounted in the drain line that permits the drain line to be opened or closed.

[0118] The disconnect fitting 1131 is arranged to receive a quick disconnect coupling 1134 that is attached to the downstream end of a flexible supply line 1135. The proximal end of line 1135, in turn, is connected to a four-way reversing valve unit 1137 secured to the discharge side of a blower 1140.

[0119] The blower 1140, with the associated valves and piping, is mounted upon the back of a self-propelled vehicle 1141 so that it can be transported over the golf course from

one green to another. Alternatively, the blower 1140 and associated components may be mounted upon a trailer that can be moved from green to green by any suitable prime mover. In an embodiment where the blower 1140 is used on a transport unit, the blower 1140 is driven by a gasoline motor that is also mounted on the back of the vehicle and is attached to the drive shaft of the blower. In other embodiments, motive power to the blower 1140 may also be furnished by an available power take-off, an electrical driver such as an electric motor, or the blower can be driven using high pressure water or fluid that runs a turbine or other fluid driven motion source.

[0120] The four-way flow reversing unit 1137 operates as described above with regard to the four way valve of FIGS. 6 and 7. When the four way valve 1137 is configured as shown in FIG. 6, ambient air is delivered to the inlet side of the blower and is pumped into the duct network, the air is passed through the lines of the duct network and uniformly distributed throughout the gravel bed 14 beneath the green. The blower delivers low pressure air at a high enough volume such that the air is pushed upwardly through the soil and subsoil of the green back into the surrounding ambient. Air moving upwardly through the green can be used to aerate the soil or to heat and cool the soil.

[0121] Reversing the valve positions in the four way valve 1137 as shown in FIG. 7 places the inlet side of the blower in communication with supply line 1135 and the discharge side of the blower in communication with the surrounding ambient. This, in turn, causes ambient air to be drawn downwardly through the green profile. Any excess moisture in the soil accordingly will be pulled into the duct lines and delivered into the drain line 1120. The reverse flow arrangement is suitable for use when the ambient temperature is more within the desired range than the soil temperature to provide for cooling or warming of the greens. This vacuum position also allows for the draw down of pesticide vapors to remove them from the user surface.

[0122] Preferably, when air is being pumped by the blower into the duct network, valves 1133 and 1125 will normally be closed and valve 1130 opened so that ambient air can pass directly into the gravel bed 14 beneath the green. When the blower is arranged to draw air downwardly through the green, valve 1133 will be opened to allow moisture to pass into

the drain line. When the quick disconnect coupling is removed, thus separating the blower from the duct network, valve 1130 is closed and valve 1133 is opened to permit excess moisture collected in the duct network to be gravity fed to the main drain system servicing the course.

[0123] As can be seen, one mobile pump can be utilized in the present system to service a number of greens on a golf course, a sports field and/or a leach field. Additionally, existing greens having in place drain systems can be easily retrofitted for almost immediate use in the present air treatment system. The valves servicing the system can be stationed in access pits some distance from the treatment site, and thus will not detract from the field of play.

Battery Powered Air Handling System

[0124] As mention hereinabove, in some situations, an area of interest that requires treatment with a subsurface aeration system according to the invention does not have a suitable power source available in its immediate vicinity. Alternating current (AC) motors that are suitable for operating a typical subsurface aeration system are often of a size in the 3 to 5 horsepower range, which require about 30 to 45 amps at 110 volts for their operation. However, the typical utility 110 volt power line used for irrigation satellites or for general purposes such as lighting, provides only about 10-15 amps, which is typically insufficient for operating subsurface aeration systems. As an example, on an older golf course, or in areas that are sufficiently remote from a high voltage power source, such as a 220 (or higher) volt supply, it is commonly the case that the available 110 volt AC power source when operating alone has insufficient capacity to drive a motor of suitable size to operate the air pump satisfactorily for the proper operation of the subsurface aeration system. According to principles of the invention, the subsurface aeration system in some embodiments is powered by a storage battery having sufficient capacity (e.g., high enough amp-hour rating and high enough discharge rate) to operate a DC motor that runs the air pump or blower of the system satisfactorily. In a preferred embodiment, the storage battery is a deep discharge battery. Those of ordinary skill will recognize that individual storage batteries having sufficient

voltage and current capacity, as well as series and parallel combinations of storage batteries, can be used in practicing the invention. For example, such as 6 volt, 12 volt batteries (e.g., automotive batteries), 24 volt batteries (e.g., marine batteries), and other batteries of any convenient voltage can be employed in the systems according to principles of the invention. As an example, if a 48 volt system is desired, it is possible to connect eight (8) batteries of the 6 volt type in series, or one could use a different arrangement, such as 4 batteries of the 12 volt type in series. In one embodiment, eight 6 volt deep cycle batteries, such as U.S. Battery model 2200, available from U.S. Battery Manufacturing Co., 1895 Tobacco Road, Augusta, GA 30906, are used to provide a 48 volt compound storage battery. As is well understood by application of Kirchhoff's current and voltage laws, to increase the current capacity, if needed, one could build a compound battery system by connecting two or more "strings" of series-connected batteries in parallel, wherein each series "string" comprises batteries having a total voltage value that is substantially equal to every other "string" in the compound battery system. In view of the forthcoming change of automotive battery technology to batteries operating in the range of 36-42 volts, one can expect that batteries operating at those voltages will be come more economical, and can be foreseen as being applicable to the inventions described herein. In another preferred embodiment, the storage battery (or a plurality of storage batteries) provides a working voltage of 48 volts.

[0125] FIG. 13 is a high level block diagram of a system 1300 employing a storage battery. In FIG. 13, a DC motor 1310 is mechanically connected to a blower or air pump 19 by a shaft 1312, which can include a transmission and/or clutch mechanism as is well known in the motor/blower arts. In some embodiments, the motor 1310 is a Briggs and Stratton Etek™ permanent magnet Electric Motor System 48 volt motor. Other DC motors can be used in other embodiments. FIG. 17 is a schematic diagram 1700 showing a showing a test circuit for a DC motor 1710 driven by a 48 volt battery 1720. A rheostat 1730 is connected between the battery 1710 and the motor 1720 so that a resistance can be introduced at start-up, and removed as the motor begins to operate. The rheostat 1730 comprises a variable resistor configured to handle a peak current of some tens to approximately 150 amps.

[0126] The blower or air pump 19 is connected by way of output line 1302 and input

line 1304 to a subsurface aeration system that can provide at least one of air under pressure and a partial vacuum, such as those shown in FIGS. 1 through 10 above, and the details described and shown there will not be repeated here. The DC motor comprises power terminals 1314, 1316 for operating the DC motor 1310 when suitable DC voltage and current are applied thereto. In the embodiment shown in FIG. 13, a storage battery 1320 is provided for providing DC power at the required current and voltage needed by the motor 1310. In some embodiments, the storage battery 1320 is a bank of batteries interconnected to supply a desired working voltage and a suitable current, such as a series-connected set of eight batteries, each battery being a six volt deep discharge lead acid battery, thereby providing a current of 45 to 60 amps at 48 volts nominal working voltage. In one embodiment, such a battery bank provides about 30 minutes of operating time in a period of about 210 minutes, or a duty cycle of about 15%. In some embodiments, the deep discharge batteries are discharged to only an extent of 30 to 40 percent of their working capacities, both to prolong their operating life, and to keep recharge time to acceptable values. The storage battery comprises terminals 1324 and 1326 that can be connected to motor terminals 1314 and 1316, respectively. In FIG. 13, the connection of terminal 1324 and terminal 1314 is shown as being accomplished by a single pole switch 1354 which can be opened, disconnecting the storage battery from the motor 1310, and which switch 1354 can be closed, thereby connecting the storage battery 1320 to the motor 1310. For simplicity, the second connection between terminal 1326 of the storage battery 1320 and terminal 1316 of the motor is shown without an intervening switch; those of ordinary skill in the electrical arts will understand that switch 1354 could be replaced with a two pole switch that connects or disconnects, depending on its state, both of the connections between the storage battery 1320 and the motor 1310.

[0127] The battery 1320 requires recharging, for example when a sufficiently long period of operation of the motor 1310 and blower 19 has elapsed. Accordingly, the system of FIG. 13 further comprises a source of AC power 1340, such as the above-mentioned 110 volt AC power source when operating alone has insufficient capacity to drive a motor of suitable size to operate the air pump 19 satisfactorily. In other embodiments, other sources of electrical power can be used in place of the source of AC power 1340. Examples of other

sources of electrical power include a solar cell array, a generator driven by an engine (such as engines that use gasoline, diesel, compressed gas, or natural gas as fuel), a wind turbine, and a fuel cell. The AC power source 1340 is electrically connected to an AC-to-DC converter 1330, such as a full- or half-wave rectifier circuit, with or without filtering. The preferred AC-to-DC converter 1330 is a high efficiency full-wave rectifier with filtering. The terminals 1334 and 1336 of the AC-to-DC converter (or battery charger) 1330 connect electrically with the corresponding terminal 1324 and 1326 of the storage battery 1320. The AC power source 1340 and the AC-to-DC converter 1330 when operative are configured to fully charge storage battery 1320 to its rated capacity over a reasonable period of time, such as a period of tens of minutes to hours. In some embodiments, the battery charger comprises a transformer. In some embodiments, the transformer is part of the AC-to-DC converter 1330. In some embodiments, the battery charger operates at an input voltage of 110 volts AC and draws 10 to 15 amps, while providing an output of 48 to 60 volts DC at 18 to 20 amps.

[0128] In FIG. 13, the connection of terminal 1324 and terminal 1334 is shown as being accomplished by a single pole switch 1356 which can be opened, disconnecting the storage battery 1310 from the AC-to-DC converter 1330, and which switch 1356 can be closed, thereby connecting the storage battery 1320 to the AC-to-DC converter 1330. For simplicity, the second connection between terminal 1326 of the storage battery 1320 and terminal 1336 of the AC-to-DC converter 1330 is shown without an intervening switch; those of ordinary skill in the electrical arts will understand that switch 1356 could be replaced with a two pole switch that connects or disconnects, depending on its state, both of the connections between the storage battery 1230 and the AC-to-DC converter 1330. In one embodiment, the common connection of terminals 1316, 1326 and 1336 is defined as ground 1338. Alternatively, the voltage at the common connection of terminals 1316, 1326 and 1336 can be shifted to any convenient value of voltage, using well-known circuitry.

[0129] FIG. 13 further indicates the presence of a control circuit 1350 that is responsive to commands. The commands are communicated to the control circuit 1350 over a communication line 1360, which is at least uni-directional, and in some embodiments is bi-directional. The control circuit 1350 is operatively coupled via bi-directional control and data

line 1351 to the storage battery 1320 to control a connection of the storage battery 1320 to provide power to the motor 1310, for example by controlling the state of switch 1354. The control circuit 1350 in some embodiments receives information transmitted on bi-directional control and data line 1351 about the condition or state of the storage battery 1320 from local sensors, such as current and voltage sensors. In other embodiments, the current and voltage sensors include local logic capability, which can communicate with the control circuit 1350 to inform it of a condition requiring attention, or the local logic capability can be configured to take corrective or remedial action as necessary. The control circuit 1350 is also operatively coupled via bi-directional control and data line 1352 to the battery charger 1330 to control a connection of the storage battery 1320 to the battery charger 1330, for example by controlling the state of switch 1356. In some embodiments, the battery charger 1330 communicates a status or condition to the control circuit 1350 using the bi-directional control and data line 1352. In some embodiments, the battery charger 1330 comprises local logical capability, which can communicate with the control circuit 1350 to inform it of a condition requiring attention, or the local logic capability can be configured to take corrective or remedial action as necessary. In some embodiments, the control circuit 1350 is also operatively coupled to the combination of AC power source 1340 and AC-to-DC converter 1330 by bi-directional control and data line 1353, whereby the control circuit 1350 can turn the combination of AC power source 1340 and AC-to-DC converter 1330 on and off as may be convenient or necessary, and data can be sent from the combination of AC power source 1340 and AC-to-DC converter 1330 to the control circuit 1350 as necessary. As will be understood by those of ordinary skill in the electronic control arts, the system in some embodiments includes feedback from the controlled components (e.g., storage battery 1320, battery charger 1330, motor 1310) that provides the control circuit 1350 data or information which are useful in performing control actions. In other embodiments, there is additionally control circuitry and logic at the component being controlled, which control circuitry and logic also has the capacity to perform control functions.

[0130] In one mode of operation (which we shall term "mode one"), the storage battery 1320 alone is used to provide power to the motor 1310. In a second mode of

operation (which we shall term "mode two"), the storage battery 1320 and the combination of the AC power source 1340 and AC-to-DC converter 1330 are both connected to the motor 1310 to provide power thereto. In the second mode, the combination of AC power source 1340 and AC-to-DC converter 1330 can be understood to provide power that supplements the power being provided by the storage battery 1320, thereby reducing the discharge rate that the storage battery 1320 experiences, assuming that the operating point of the motor 1310 in mode two is the same as would be the case under operation in mode one. Equivalently, one can understand the operation of the combination of AC power source 1340 and AC-to-DC converter 1330 as recharging the storage battery 1320 while the storage battery 1320 is being discharged because of the drain represented by the operation of the motor 1310. In any event, the net effect is to extend the time of operation of the motor 1310 above what would be possible using the storage battery 1320 alone. Those of ordinary skill will also recognize that the system described above can be modified by the addition of additional storage batteries 1320 and additional switching circuitry, so that a first storage battery 1320 can provide power to motor 1310 while a second storage battery 1320 (not shown in FIG. 13) is being recharged by the combination of AC power source 1340 and AC-to-DC converter 1330. In some embodiments, during "mode two" operation when a golf green is wet, the storage battery provides approximately 35 to 45 amps to the DC motor and the battery charger provides up to 20 amps. In some embodiments, during "mode two" operation when a golf green is dry, the storage battery provides approximately 65 to 75 amps to the DC motor and the battery charger provides about 18 to 20 amps.

[0131] In some embodiments, the control circuit 1350 is configured to disconnect the storage battery if the drain on the storage battery becomes too great (i.e., exceeds a defined current) such as is commonly achieved with a circuit breaker, or if the storage battery voltage falls below a specific lower threshold or setpoint voltage. In some embodiments, a 48 volt nominal working voltage system has a lower threshold voltage of 44 volts. In some embodiments, the control circuit 1350 waits a defined period of time to permit a temporary fault to be cleared before acting, for example the control circuit 1350 may have a 10 minute delay. In some embodiments, the control circuit 1350 is configured to cause the battery

charger to cease charging when a specific higher threshold voltage is attained.

[0132] In some embodiments, the operation of the system using the storage battery system 1300 is as will now be described. The system is turned on and operated by any of a manual operation of a user, a timer, and a command issued by a user or a program operating a programmable computer system (e.g., a programmable master control module) such as a personal computer (PC), a personal digital assistant (PDA), a cellular telephone, a programmable logic controller (PLC), and industrial controller, whether directly connected to the system, or connected by way of a hard-wired communication link, a wireless communication link, a fiber-optic communication link, a communication network, a telephone communication link, an optical communication link, and a packet-switched communication link.

[0133] At system turn on, AC line voltage is provided to operate a DC relay and logic power supply. Typically, the power supply operates at 24 volts DC. A "start" sequence including a "soft start" current limitation to the blower motor is initiated. The DC motor in one embodiment is a brush motor, which represents a substantially zero impedance when not operating. In this embodiment, a starting resistor of approximately 0.3 ohm is initially switched into series connection between the DC motor and the storage battery, which resistor limits the initial current (or surge current) flowing to the motor to the order of 100 amps, e.g., 48 volts driving 0.3 ohms will cause 48/0.3 = 160 amps. A relay is provided to short out the resistor after a brief period, such as 1 second, once the motor begins to operate, at which time the windings have a back electromotive force present, which causes the current to maintain a finite value. The current draw through the motor is then determined by the load on the motor represented by the blower. In addition, a contactor between the charger and the storage battery is opened, so that the charger is reset to a "charge" state when the contactor is closed again. This operating condition is a "mode one" operating condition. In other embodiments, a solid state controller can be used to control the current supplied to the motor on startup, and to control the motor during operation. In yet another embodiment, it is optionally possible to start the motor without any "soft start" control by connecting the motor directly to the storage battery. In the instance where no soft start is used, stresses are placed both on the motor at

startup and on the battery which has to supply a large surge current. In addition, starting the motor without a controlled acceleration places significant stresses on the coupling between the motor and the blower.

[0134] A short time, for example 5 seconds, after the motor begins to operate with the 0.3 ohm resistor shorted out, the contactor between the charger and the storage battery is closed, causing the battery charger to begin to provide charge to either or both of the storage battery and the DC motor, which is described hereinabove as a "mode two" operating condition. The DC motor drives the blower during which time charge is drained from the storage battery.

[0135] The control circuit comprises a device that monitors the current being drawn from the battery (e.g., a current monitor module). In one embodiment, a Hall effect toroidal coil sensor with built in adjustable sense level is used. The sensor senses DC current flow in a wire brought through a hole located in the center of the module. Current sensing is done by an internal Hall effect device. When the forward current flow goes above a pre-adjusted set point, the output goes high. When the forward current falls below the pre-adjusted set-point, the output goes low. A reverse current flow has no effect. The current sense set point may be in the range of 0-10, 0-100 or 0-200 Amp depending on the model selected. The sensor in one embodiment is a model CS880-100 DC current sensing module available from RBE Electronics, 714 Corporation Street, Aberdeen, SD 57401, which is described at the web site www.rbeelectronics.com/cs880.htm.

[0136] In another embodiment, a shunt of resistance R ohms is used, whereby a voltage $V = IR$ is generated across the shunt in proportion to the current, I, flowing through the shunt. The power lost in the shunt is given by I^2R. For a shunt of sufficiently small resistance, even a current of 100 amps will result in a small power loss, for example $100 \times 100 \times .0001 = 10$ watts for a resistance of 0.0001 ohm (e.g., 0.1 milliohm). Under these conditions, $V = 100 \times .0001 = 0.01$ volts or 10 millivolts, a readily discernable voltage. In some embodiments, a limiting current is 75 amps, which corresponds to a shunt voltage of 7.5 millivolts. If the limiting current value is reached, the control circuit can disconnect the motor from the storage battery and the battery charger, thereby turning the system off and

protecting the storage battery. The control circuit can also disconnect the motor from the storage battery and the battery charger in the event that the storage battery voltage falls below a predefined lower threshold voltage, as described herein above.

[0137] The control circuit 1350 in some embodiments comprises a storage battery discharge monitoring module. In some embodiments, the storage battery discharge monitoring module is a device that integrates with respect to time the amount of current drawn from the battery, for example by using the instantaneous values provided by the current monitor module. In one embodiment, a battery storage discharge monitoring module is implemented by using an analog-to-digital converter with a sample-and-hold circuit to periodically sample the shunt voltage IR described above and to provide a digital representation thereof, which is then processed by a programmable digital computer to derive the current $I = V/R$ and to integrate by summation the value $I \times \Delta t$, where Δt represents a time interval between current observations. In another embodiment, the shunt voltage is converted to a pulse train in a voltage controlled oscillator, and the pulses are counted, thereby providing an instantaneous measure of voltage V, and hence of current I. When the integrated value representing amp-hours reaches a threshold value, such as 30 amp-hours, the control circuit can shut off the motor and blower by disconnecting the storage battery/battery charger and the DC motor. In an alternative embodiment, the motor can be shut off after a specified time period, such as 30 minutes, without actually measuring the number of amp-hours of discharge current. In some embodiments, the time of operation can be estimated based on the environmental conditions of the area of interest, for example using a look-up table, which table can be generated by actual experience or can be generated by calculation using a mathematical model.

[0138] During operation, the control circuit can identify and can control the state of the various valves in the subsurface aeration system. For example, the four way reversing unit comprises valves that need to be opened or closed in the correct relationship so as to define a flow direction for air, thereby allowing the system to provide a selected one of air under pressure and a partial vacuum, as explained hereinabove. The control circuit identifies the state of each of the valves in the four way reversing unit. The state of one or more valves

may be recorded in a machine readable memory as a truth table for each defined type of operation of the system. In some embodiments, the control circuit accesses the truth table to determine the correct valve configuration for the type of operation that is intended. The control circuit can thereby determine whether the subsurface aeration system is configured to deliver pressurized air or partial vacuum, or if the four way reversing valve is misconfigured (i.e., whether one or more of the valves thereof is in an undefined state). The control circuit compares the then-current configuration to the configuration needed for the type of operation that the system is supposed to be performing. As needed, the control circuit adjusts the valve positions or states to conform the system to the desired operation. In another embodiment, the control circuit uses a "brute force" configuration approach, in which it does not determine whether a valve is correctly or incorrectly configured, but merely issues commands to configure each valve according to a predefined set of configurations. The system can then be operated under the presumption that each valve is properly configured, whether it was so configured originally or not.

[0139] In normal operation, after the motor is turned off by disconnecting the storage battery/battery charger from it, the battery charger remains connected to the storage battery to recharge the storage battery. The battery charger remains in an operating ("on") state and recharges the storage battery until the storage battery is observed by the control circuit to be fully charged. The control circuit turns off the battery charger and disconnects the storage battery when the storage battery is fully charged. The state of charge of the storage battery can be monitored by observing any one of several operating parameters of the storage battery, such as the time rate of change of voltage, dv/dt, of the storage battery; the instantaneous voltage of the storage battery; or by measuring the amount of charge actually entering the battery, using the shunt method described hereinabove. When the storage battery is deemed to have been recharged, the battery charger is disconnected.

[0140] In some embodiments, the components of the power supply portion of the system, including the storage battery, the AC power source, the AC-to-DC converter, the various switches, relays and other interconnect hardware are all situated within enclosures that can be opened by authorized personnel, such as users of the system or individuals trained

to install and repair the system, but not by unauthorized individuals. The presence of enclosures is a safety measure, and the enclosures in some embodiments are provided with safety switches (or limit switches) at locations such as doors or panels that can be opened, so that the system is disabled upon the opening of a door or panel of the enclosure. In some embodiments, there are provided jumpers or other devices for defeating an activated safety switch so that the electrical components can be tested by an authorized person even with a door open or with a panel removed, as is well known in the electrical arts. In some embodiments, ground fault circuit interrupter (GFCI) devices are provided at the 110 volt AC power mains to disable the system if an electrical fault occurs.

[0141] FIG. 13A is a high level block diagram illustrating an embodiment of a battery 1320, a controller 1325, a motor 1310 and a blower 19. In some embodiments, the controller 1325 is a soft start resistor and relay controls for switch the resistor into and out of the circuit. In some embodiments, the controller 1325 is a rheostat and the necessary relay contacts. In some embodiments the controller is a solid state controller that can control the current provided to the motor so as to limit current surges and control motor speed and acceleration, for example a pulse width modulation device. In some embodiments, the controller 1325 is a switch.

[0142] FIG. 14 is a high level block diagram of a second storage battery system 1400 further comprising an inverter 1460 and an AC motor 1410. Again, the system of FIG. 14 comprises a source of AC power 1440, such as the above-mentioned 110 volt AC power source when operating alone has insufficient capacity to drive a motor of suitable size to operate the air pump 19 satisfactorily.

[0143] In FIG. 14, an AC motor 1410 is mechanically connected to a blower or air pump 19 by a shaft 1412, which can include a transmission and/or clutch mechanism as is well known in the motor/blower arts. The blower or air pump 19 is connected by way of output line 1402 and input line 1404 to a subsurface aeration system that can provide at least one of air under pressure and a partial vacuum, such as those shown in FIGS. 1 through 10 above, and the details described and shown there will not be repeated here. The AC motor comprises power terminals 1414, 1416 for operating the AC motor 1410 when suitable DC

voltage and current are applied thereto. In the embodiment shown in FIG. 14, a storage battery 1420 is provided for providing DC power to the inverter 1460, which in turn provides the required current and voltage needed by the motor 1410. The inverter 1460 comprises terminals 1464 and 1466 that can be connected to motor terminals 1414 and 1416, respectively. In FIG. 14, the connection of terminals 1464 and 1466 to terminals 1414 and 1416 respectively is shown as being accomplished by a two pole switch 1462 that connects or disconnects, depending on its state, both of the connections between the inverter 1460 and the motor 1410. . The two pole switch 1462 is controlled by the control circuit 1450 via a bi-directional control and data line 1451.

[0144] The battery 1420 requires recharging, for example when a sufficiently long period of operation of the motor 1410 and blower 19 has elapsed. The AC power source 1440 is electrically connected to an AC-to-DC converter 1430, such as a full- or half-wave rectifier circuit, with or without filtering. The preferred AC-to-DC converter 1430 is a high efficiency full-wave rectifier with filtering. The terminals 1434 and 1436 of the AC-to-DC converter (or battery charger) 1430 connect electrically with the corresponding terminal 1424 and 1426 of the storage battery 1420. The AC power source 1440 and the AC-to-DC converter 1430 when operative are configured to fully charge storage battery 1420 to its rated capacity over a reasonable period of time, such as a period of tens of minutes to hours.

[0145] In FIG. 14, the connection of terminal 1424 and terminal 1434 is shown as being accomplished by a single pole switch 1456 which can be opened, disconnecting the storage battery 1410 from the AC-to-DC converter 1430, and which switch 1456 can be closed, thereby connecting the storage battery 1420 to the AC-to-DC converter 1430. For simplicity, the second connection between terminal 1426 of the storage battery 1420 and terminal 1436 of the AC-to-DC converter 1430 is shown without an intervening switch; those of ordinary skill in the electrical arts will understand that switch 1456 could be replaced with a two pole switch that connects or disconnects, depending on its state, both of the connections between the storage battery 1230 and the AC-to-DC converter 1430.

[0146] FIG. 14 further indicates the presence of a control circuit 1450 that is responsive to commands. The commands are communicated to the control circuit over a

communication line 1459, which is at least uni-directional, and in some embodiments is bi-directional. The control circuit 1450 is operatively coupled via bi-directional control and data line 1455 to the storage battery 1420 to control a connection of the storage battery 1420 to the inverter 1460, to provide power to the motor, for example by controlling the state of switch 1458. The control circuit is also operatively coupled via bi-directional control and data line 1453 to the battery charger 1430 to control a connection of the storage battery 1420 to the battery charger 1430, for example by controlling the state of switch 1456. In some embodiments, the control circuit 1450 is also operatively coupled to the combination of AC power source 1440 and AC-to-DC converter 1430 by bi-directional control and data line 1453, whereby the control circuit 1450 can turn the combination of AC power source 1440 and AC-to-DC converter 1430 on and off as may be convenient or necessary. As will be understood by those of ordinary skill in the electronic control arts, the system in some embodiments includes feedback from the controlled components (e.g., storage battery 1420, battery charger 1430, motor 1410) that provides the control circuit 1450 data or information which are useful in performing control actions. In other embodiments, there is additionally control circuitry and logic at the component being controlled, which control circuitry and logic also has the capacity to perform control functions.

[0147] In one mode of operation (which we shall term "mode one"), the storage battery 1420 alone is used to provide power to the motor 1410 by way of inverter 1460. In a second mode of operation (which we shall term "mode two"), the storage battery 1420 and the AC power source 1440 are both connected to the motor 1410 to provide power thereto. The AC power source 1440 is connected to the motor by way of a two-pole switch 1443. The two pole switch 1443 is controlled by the control circuit 1450 via a bi-directional control and data line 1452. In some embodiments, phase and frequency sensing hardware and/or software and control circuitry are provided to permit the synchronization of the phase and frequency of the AC power source and the output of the inverter 1460 so that the power from the two sources adds and does not destructively interfere when operated in "mode two." In one embodiment, the inverter 1460 comprises phase and frequency sensing hardware, and is configured to adjust its output to conform to the phase and frequency of the AC power source

1440.

[0148] In the second mode, the AC power source 1440 can be understood to provide power that supplements the power being provided by the storage battery 1420 by way of the inverter 1460, thereby reducing the discharge rate that the storage battery 1420 experiences, assuming that the operating point of the motor 1410 in mode two is the same as would be the case under operation in mode one. In an alternative embodiment, the operation of the combination of AC power source 1440 and AC-to-DC converter 1430 can be used to recharge the storage battery 1420 while the storage battery 1420 is being discharged by way of the inverter 1460 because of the drain represented by the operation of the motor 1410. In any event, the net effect is to extend the time of operation of the motor 1410 above what would be possible using the storage battery 1420 alone. Those of ordinary skill will also recognize that the system described above can be modified by the addition of additional storage batteries 1420 and additional switching circuitry, so that a first storage battery 1420 can provide power to motor 1410 while a second storage battery 1420 (not shown in FIG. 14) is being recharged by the combination of AC power source 1440 and AC-to-DC converter 1430.

[0149] The operation of the system using the AC motor of FIG. 14 is substantially similar to that using a DC motor, with certain obvious variations. The measurement of battery discharge current is measured between the storage battery and the inverter 1460. There is no need for the 0.3 ohm starting resistor and all of the hardware and operating steps associated with that resistor are omitted.

[0150] The command that either of control circuit 1350 of FIG. 13 or control circuit 1450 of FIG. 14 receive can be a command generated by a programmable master control circuit, such as a programmable computer, a commend generated by the control circuit itself based on a program or generated by a hard-wired logic circuit, or a command from a user. The various command scenarios will be discussed in greater detail hereinbelow.

[0151] At least one embodiment of the battery powered air handling system of the invention was constructed and tested, successfully demonstrating the principles of the invention. In this embodiment, a Briggs and Stratton DC motor was used to drive an aluminum blower fan. The air driven by the fan was carried by a conduit made from 8 inch

diameter corrugated plastic pipe. Different caps were attached to the delivery end of the conduit to simulate various conditions of air impedance that the air handling system was expected to encounter. The caps included devices having fixed discharge surface areas, as well as a variable damper that could be set within a range of positions representing different impedances to air flow. The parameters that were measured included the battery voltage and current, the speed of the fan in revolutions per minute (RPM), the flow velocity of air in linear feet per minute, and the back pressure in inches of water. Air linear flow velocity was converted to cubic feet per minute (CFM) based on the size of the conduit.

[0152] FIG. 15 is a graph of the observed values for electric current and for back pressure as a function of air flow delivered. The pressure observed did not appreciably differ from 22 inches of water for flow rates ranging from about 200 CFM to about 1200 CFM. These results are satisfactory. The observed electric current varied in the range of about 38 amps at the 200 CFM flow rate to about 95 amps at the higher flow rates. The battery voltages observed were close to the nominal 48 volts under all test conditions, ranging from a high of about 51 volts at low flow rate to about 47 volts at higher flow rates. The motor efficiency was consistently in the 90 to 95 percent range, as computed from the electrical power supplied by the battery and the estimated torque power delivered by the motor. The motor parameters were not graphed.

[0153] Using the observed operating parameters, values were computed for electric power consumed, power transmitted to drive the flowing air, and the efficiency of the fan, using standard calculations well known in the art and described in the technical literature. FIG. 16 is a graph of the calculated results for electric power consumed, power transmitted to drive the flowing air, and the efficiency of the fan as a function of air flow delivered. The fan efficiency at low flow rates of approximately 250 CFM are relatively low, in the range of 35 to 40 percent. The fan efficiency for higher flow rates (e.g., above about 550 CFM) is significantly higher, ranging from 67 to 77 percent.

[0154] FIG. 18 is a schematic diagram of a motor-blower assembly 1800 useful in practicing the invention. The motor 1810 is a DC permanent magnet motor. The blower 1820 comprises a housing 1822, which is constructed from a suitable protective material,

such as 10 gauge sheet steel, having apertures for air to enter therein, and for air to be expelled therefrom. The apertures are not shown in FIG. 18, but are well known in the motor-blower arts. The blower comprises a fan 1824. In one embodiment, the blower is a Twin City fan model 18W8, available from Twin City Fan & Blower, 5959 Trenton Lane North, Minneapolis, MN 55442-3238.

[0155] FIG. 19 is a plan diagram 1900 of a motor-blower 1910, a battery bank comprising batteries 1920 and a conduit 1930 situated with a chamber 1940. The chamber 1940 may be above ground or below ground. The chamber 1940 is provided to protect its contents from the elements and from being vandalized or stolen. FIG. 19 does not show the various connections of the components.

[0156] FIG. 20 is a plan diagram 2000 that shows an arrangement of components employed in testing the noise level generated during the operation of a system built according to the principles of the invention. The components shown include a location for a housing 2020 used to contain the motor-blower (not shown, but see FIG. 19), a location of a storage battery array 2030, and the location of a data collection point 2040 situated at a distance of approximately 15 feet from a side of the location of the housing 2020. The housing comprises a vent 2022 and a duct 2024 such as would be used in a subsurface aeration conduit providing aeration services to a golf green. Noise levels were recorded for above ground configurations, with and without a silencer. Noise levels as low as 66 db were observed. It is expected that even lower noise levels can be achieved using the principles of the invention, for example by adding foam insulation to the housing 2020.

Golf Course Environmental Management System

[0157] Another feature of the invention relates to systems and methods for managing a plurality of areas of interest within a golf course. The systems and methods of the invention use one or more sensors to provide information about the state of various environmental variables, such as an ambient air temperature, a soil temperature, and a soil moisture content. The systems and methods disclosed use the information to determine whether there is a need to adjust one or more of the environmental conditions, and if so, how best to effect the

necessary adjustment or adjustments.

[0158] FIG. 21 shows a prior art air handling device 2110 that includes a reversing shuttle 2120 that is connected to a fan box 2130. The reversing shuttle 2120 can operate in either of two configurations, a first one in which air moves in a first direction, and a second configuration in which air moves in a second direction, which is opposite to the first direction. FIG. 21 shows the reversing shuttle in one configuration. Reversing shuttle 2120 includes a vacuum side damper 2122 on one side and a pressure side damper 2123 on another side. A connection portion 2124 connects to a supply line (not shown) that connects air handling device 2110 to a duct network 2315 (FIG. 23) of a sports field (not shown). Dampers 2122, 2123 are preferably linked together so that when one damper is closed, the opposite damper is open, and vice versa. Dampers 2122, 2123 can be opposed operation actuated dampers to ensure that dampers 2122, 2123 are in opposed operation. A diverter damper 2125 extends from a pivot point 2126 to a seat 2127a when air handling device 2110 is in a vacuum mode and to a seat 2127b when air handling device 2110 is in a blowing mode. Diverter damper 2125 and seats 2127a, 2127b are preferably curved so as to avoid inefficiencies in the system by minimizing turbulence and maintaining laminar flow.

[0159] Diverter damper 2125 is preferably of carbon steel, but other materials that are suitably strong and durable can be used. Diverter damper 2125 is preferably manually, electrically, or pneumatically actuated. When electrically or pneumatically actuated, a separate manual control is optional. Diverter damper 2125 could be hydraulically actuated, but for most applications, this is not required.

[0160] Fan box 2130 includes a fan inlet 2131 which is connected on one end to an inlet box 2132 and on the other end to reversing shuttle 2120. Inlet box 2132 is in turn connected to a fan housing 2133 which preferably contains a conventional impeller type fan (not shown), although selecting the particular type of fan for a given installation is within the ability of one skilled in the art. Fan housing 2133 is connected to a fan outlet 2134 which in turn is connected to reversing shuttle 2120. The geometries of fan inlet 2131 and fan outlet 2134 are such as to prevent inefficiencies in the system due to turbulence.

[0161] When diverter damper 2125 is positioned as shown in FIG. 21, air enters

reversing shuttle 2120 via connector 2124 as shown by arrow (a) because damper 2122 is closed and damper 2123 is open. The air moves through fan box 2130 as shown by arrow (b) and exits to atmosphere through reversing shuttle 2120 as shown by arrow (c).

[0162] FIG. 22 shows the diverter in a second configuration. Diverter damper 2125 is seated against seat 2127b and damper 2122 is open while damper 2123 is closed. The air therefore enters reversing shuttle 2120 as shown by arrow (d), moves through fan box 2130 as shown by arrow (b), and exits reversing shuttle 2120 through connector 2124 as shown by arrow (e).

[0163] Referring to FIG. 23, a prior art device has dampers 2122, 2123 and diverter damper 2125 automatically controlled by a control unit 2140 that preferably includes a microcontroller (not shown) operating to a control logic preferably input by a user via a device such as a PC 2148. The PC 2148 is optionally connected to a communications interface 2149 such as a dial-in modem or internet connection to permit remote programming of the control logic. A plurality of sensors 2142, 2144, 2146 that measure variables such as temperature, moisture, composition of soil gasses, etc, are linked to reversing shuttle 2120 via control unit 2140 to automatically control the direction of air flow through duct network 2115. This is critical when operating air handling device 2110 in an automatic mode, because if the turf being treated contains too much moisture, blowing air from air handling device 2110 through duct network 2115 can accidentally blow the turf out of the field in spots. Contrariwise, operating air handling device 2110 in a vacuum mode when the turf is already dry will extract needed moisture from the turf. Appropriate sensors such as those manufactured by Aqua-Flex, of New Zealand, placed in or just under the turf, preferably within the root zone or just below, permit proper automatic control of air handling device 2110.

[0164] Referring to FIG. 24, a prior art device includes a heat exchanger 2150 to maintain the turf at a desired temperature. For example, soccer pitches in Europe must be natural turf instead of artificial turf, and the turf/ground cannot be so frozen such that the players' cleats are unable to make an impression in the turf/ground. Temperature sensors strategically located around the pitch are tied in to control unit 2140 which is connected to

heat exchanger 2150. The control logic for control unit 2140 is preferably programmable by the user to maintain optimal field conditions using temperature and moisture as the variables to control the direction of air movement, time that air is being moved, and the temperature of the air being moved into the duct network as the operating parameters of the air handling system. In an alternate embodiment, control unit 2140 can be optionally set to control the operating parameters based on time of day and season.

[0165] Another consideration when operating prior art device in climates where freezing is likely to occur is that the specific heat of sand, which is frequently used in sports field construction, is 0.2 BTU/lb-deg F, which is only one-fifth that of water. Removing excess moisture from a sports field before the field freezes significantly reduces the amount of heat required to unfreeze the field and place it in condition suitable for sports play. In a variation of this embodiment, a supply line between air handling device 2110 and duct network 2115 is burned underground a sufficient depth to take advantage of ground effect heat exchange. The term "heat exchanger" as used in this application includes such a buried supply line.

[0166] An alternate embodiment of the air handling system of the prior art device uses manual decision-making instead of programmed logic. The output from sensors 2142, 2144, 2146 is shown on the screen of PC 2148 and interpreted by the user. The user then can use the PC to control air handling device 2110 and optionally heat exchanger 2150, or in a simpler system, control air handling device 2110 and heat exchanger 2150 manually.

[0167] FIG. 25 is a drawing showing a plurality of electromechanical subsystems, each subsystem dedicated to a specific area of a golf course, and communicating with a programmable master control module. In FIG. 25, each electromechanical system comprises a subsurface aeration conduit and an air pump in fluid communication with the subsurface aeration conduit for providing to the specific area of the golf course at least one of air under pressure and a partial vacuum. The air pump is configured to provide at least one of air under pressure and a partial vacuum, as has been described hereinabove in several embodiments. A motor is mechanically connected to the air pump. A local control module is provided that is operatively coupled to the motor. The local control module is responsive to a directive and to

a datum. The electromechanical system also comprises at least one sensor that measures an environmental parameter. The at least one sensor is in data communication with the local control module. The programmable master control module receives from at least two of the plurality of local control modules information representing a status of the respective specific area to which the local control module is dedicated, and in response to the information and to a command, the programmable master control module issues a directive to the local control module to operate the electromechanical subsystem.

[0168] In describing the system of the invention, certain words will be intended to convey particular meanings, which are not unlike their usage in common English, in order that the claim terminology will be more explicit than it might otherwise have been. The term "directive" as used herein is intended to mean an instruction from the programmable master control module to a local control module. The term "command" as used herein is intended to mean a computer instruction of a program operating on a computer or an instruction of a control logic sequence of a logic controller, or a user command for the programmable master control module. A user who issues directions of any kind to a local control module directly can be understood to have issued a directive even if the word "command" is used to express the user's action. The term "fault condition" as used herein in intended to mean that some electromechanical component or a local control module is not in proper operating order, and should be attended to (e.g., fixed, replaced). The term "alarm condition" as used herein is intended to mean that some operating condition (such as a temperature or a moisture content) is out of tolerance and needs to be corrected by operating the system, but does not imply anything about the condition of the electromechanical components. The term "setpoint" as used herein in intended to mean a value set by default, by a computer program, or by an operator to define a desired value of a parameter or condition, or an extremum of a range of acceptable values. An alarm condition occurs when a setpoint is deviated from, or an extremum of a range is exceeded. The term "closed loop operation" is well known in the computer control arts, and generally is understood to mean that a system uses a value generated as an output of a process as an input variable. "Closed loop operation" is distinguished from "open loop operation," which is used to describe a system that sets a

control parameter with an eye to obtaining a specific output, but does not monitor an output variable for using in correcting the operation of the system. In the present invention, "closed loop operation" is also used to connote that the system will start and stop automatically based on the value or values of one or more variables such as the actual temperature and moisture content of soil or turf, and the ambient air temperature, which are compared to criteria or setpoints by a computer program of logic controller.

[0169] It is believed that heretofore, there has been no system such as is described and claimed herein that has been used with regard to golf courses. The inventors are aware that some sports fields, including the soccer field of Manchester United (U.K.), the soccer field of Kilmarnock (U.K.), the baseball and softball fields at the University of Nebraska, and the football field of the Denver Broncos in Denver, Colorado, have employed similar methods of operation to those described herein. However, as stated hereinabove, it is believed that the varied conditions found in golf courses, which are appreciably different from the conditions found in a single unvarying expanse such as a football, a baseball, a softball or a soccer field, makes the application of the systems and methods of the invention to golf courses novel. See the second paragraph of the Detailed Description for examples.

[0170] The local control modules of the electromechanical subsystems receive data from the various sensors provided for the respective areas of interest. The local control modules in one embodiment are PLCs. In one embodiment, at least one of the local control modules further comprises a communication link accessible by way of a hand-held battery-powered device. In one embodiment, the hand-held battery-powered device is a selected one of a cellular telephone, a personal digital assistant (PDA), and a pocket personal computer (pocket PC). The sensors can monitor environmental parameters such as ambient air temperature, soil temperature, soil moisture, soil salinity, air pressure within a conduit, and solar radiation level, as well as other parameters such as motion within an area of interest, an image of an area of interest, sounds present at an area of interest and other information that may be useful in operating the system of the invention. In various embodiments, the sensors provide data to the respective local control modules as raw data, as digital data, or as data in a specified format.

[0171] The system of the present invention in one embodiment uses a wireless networking technology for communication between the local control modules and the programmable master control module. Advantages of a wireless system over a hard-wired system can include greater ease of installation, lowered cost of installation, greater speed of installation, and reduced chance of damage by lightning strikes as a result of the absence of a large "antenna" or "target" for lightning represented by miles of copper wiring. In a retrofit situation, a wireless installation can represent a smaller disruption to the operation of the golf course as compared to installing a hard-wired system. The communications can also be implemented using a hard-wired communication link, a fiber-optic communication link, or any other conventional communication link that can handle the transmission of data and instructions. In some embodiments, the system has the capability to communicate by way of a communication network, such as the Internet. In one embodiment, the communication network comprises a selected one of a telephone communication link, a wireless communication link, an optical communication link, and a packet-switched communication link. In one configuration, the system comprises eighteen (18) electromechanical subsystems, each one dedicated to a green of a golf course. However, the system can also be used with other portions of a golf course, such as at least a plurality of one or more golf greens, one or more fairways, one or more tee boxes, one or more walkways, one or more gallery viewing areas, one or more driving ranges, one or more putting greens, and one or more practice areas.

[0172] The programmable master control module is configured to receive information from the local control modules, and to send directives to the local control modules. The programmable master control module in one embodiment is a selected one of a programmable computer, a programmable logic controller (PLC), and a programmable industrial controller. The programmable master control module is programmed with software. In some embodiments, the software is a computer program comprises one or more computer instructions recorded on a machine-readable medium. When the computer program is executing on the programmable master control module, one or more setpoints are defined for the operation of each electromechanical subsystem. The programmable master control module can compare a setpoint (or a range of acceptable values defined by a first extremum,

such as a low soil temperature setpoint, and a second extremum, such as a high soil temperature setpoint, to an actual value of an environmental parameter observed by a sensor. A single value setpoint can include a tolerance about the setpoint (e.g. X degrees F, plus or minus 0.5 degrees F.). If the actual value of the environmental parameter is within an acceptable range, the programmable master control module can indicate that fact to a user of the system, for example, by displaying on a display the value in green. The programmable master control module can determine if an alarm condition exists, for example when one or more actual values of environmental parameters fall outside acceptable ranges. If the actual value is outside of an acceptable range, the programmable master control module can indicate that an alarm condition exists, and the fact that caused the alarm to a user of the system, for example, by displaying on a display an out-of-range value in red, by displaying the value with a unique font or a unique visual or audible attribute, by for example by flashing the value or emitting a sound. Optionally, the display also indicates the acceptable range for the out-of-range value. In some embodiments, the programmable master control module displays in a defined manner to a user the values of parameters that are being controlled to bring an out-of-range parameter within an acceptable range, for example displaying a value in yellow while the value is out-of-range and the system is taking action to adjust or correct the value. Similar displays are optionally provided at a local control modules when a user is operating the respective local control system directly, and/or at a remote location when a user is communicating with the system from such a remote location.

[0173] The programmable master control module can be programmed to institute a remedial action if an alarm condition exists. For example when one or more actual values of environmental parameters fall outside acceptable ranges, the programmable master control module determines the status of the particular area of interest. In some embodiments, a truth table is provided for each area of interest, including at least the one or more setpoints or setpoint-defined ranges for environmental parameters. The programmable master control module determines what corrective or remedial action should be instituted by performing one or more operations, such as comparing the status to a list of predefined remedial actions to be issued as directives, or by performing logical operations configured to yield one or more

directives. The programmable master control module issues one or more directives to the respective local control module to operate the respective electromechanical subsystem to take the remedial action. The programmable master control module is configured in one embodiment to repeat from time to time the determination of the status of the particular area if interest, and while the determination indicates that additional remedial action is needed, directing the local control module to operate the subsurface aeration system to perform the necessary action. When the programmable master control module determines that the status of the area of interest conforms to the acceptable setpoint values, the programmable master control module directs the local control module to turn off the subsurface aeration system.

[0174] The programmable master control module is programmed to accept commands from an authorized user of the system, for example from a greens keeper, using an input device such as a keyboard. In some embodiments, the system is programmable to require that the user identify him- or herself to the system, for example with a token, such as a user name, a key, or a machine-readable card, and/or with a password or identification number, so as to prevent unauthorized operation of the system. In some embodiments, the system can transmit information for display to a user at a remote location and can receive information and commands from the user. For example, the greens keeper can review the status of one or more areas of a golf course from home, and as needed, can control the actions of the system from that remote location. The input and/or responses of the user can include commands, answers to queries and/or replies to information (by way of dialog boxes, radio buttons, and sliders as are well known in the computer interface arts), information in the form of files (such as new or improved programs), and updated setpoints. In some instances, the user is an individual or a computer associated with the vendor or supplier of the system.

[0175] The system of the invention can be programmed to operate at specific times, for example, during the evening or night when the areas of interest are not being used. Sensors can be used to detect the presence of players (including the data provided by any one or more of motion detection by motion sensors, visual images provided by electronic cameras, and sound detection by microphones) so that operation of certain features of the invention, such as the irrigation system, can be overridden or suppressed at appropriate times.

In an alternative embodiment, infrared sensors are provided to detect infrared signals that may represent body heat or heat from a motor of a vehicle, such as a golf cart. In order to determine whether detected motion is caused by intruders, the system can activate one or more lights to permit visual signals to be recorded at night.

[0176] In some embodiments, the control of a specific area of interest can be accomplished using the local control module. In such instances, the local control module comprises a controller such as a PC, a PLC, or another microprocessor-based controller. The local control module operates software or a control logic sequence to receive data from one or more sensors, and to analyze the data to determine if any remedial action is necessary. If remedial action is needed, the local control module institutes the remedial action, and terminates the remedial action when a suitable outcome is obtained. The local control module in such an instance communicates with the programmable master control module to provide status information, so that a user of the system can be fully apprised of what transpires.

[0177] In some instances, a user of the system interacts with a local control module of a specific area of interest in a local mode. For example, when on site, a greens keeper can operate a local control module to perform a necessary operation of the electromechanical subsystem dedicated to the area of interest. The greens keeper might want to make specific adjustments, perform maintenance, or otherwise personally oversee an operation of the system at that location. Conveniently, a user can communicate with and control a local control module using a local display and a touch pad, a touch screen, a keyboard, or another convenient interface. Keyboards proving access by way of infrared interfaces, such as an IrDA interface, are also known. The user can communicate with at least one of the local control modules that further comprises a communication link accessible by way of a hand-held battery-powered device. In one embodiment, the hand-held battery-powered device is a selected one of a cellular telephone, a personal digital assistant (PDA), and a pocket personal computer (pocket PC), which the user uses to gain access the local control module and to operate it, and thereby the specific electromechanical subsystem.

[0178] In some embodiments, the programmable master control module also provides

a data logging capability and a data trending capability. The data logging and trending capabilities can be provided using any commercial database management software, proprietary database management software, and/or spreadsheet software. Data logging and trending is well known in the information technology arts, and will not be discussed at length herein.

[0179] The system provides fault detection capability. In some embodiments, the programmable master control module (by way of a local control module) monitors that status of components of the system. For example, the local control module can determine if a motor is drawing excessive power, or if the voltage across a storage battery is out of tolerance. The fault condition can be exhibited or enunciated to a user at any of a local control module, the programmable master control module, and a remote location when a user communicates with the system from such a remote location.

[0180] FIGS. 26-29 are drawings depicting exemplary embodiments of a local control module with different features. FIG. 26 shows an embodiment of a local control module 2610 that has a basic complement of features, including the ability to control the on or off state of a motor-blower 2612, the ability to control whether the motor-blower operates to provide air pressure or to provide a partial vacuum 2614, the ability to define a preset start time for operating the subsurface aeration subsystem controlled by the local control module 2616, and the ability to display fault conditions 2618. The local control module 2610 also has the ability to sense a flood condition 2620 in a vault (e.g., water entering the vault) in which the motor-blower and other components are secured, and can provide power 2622 to operate a sump pump and/or its associated power supply so as to prevent or counteract the flooding condition. The local control module can send a command 2630 to the reversing valve to determine a partial vacuum or air pressure configuration (e.g., actuator vacuum/pressure position). The local control module can send a command 2640 to activate or to deactivate the motor-blower, and in some embodiments, can activate/deactivate as many as six motor-blower devices. A vault may be located below ground or above ground. With an above ground vault, the controls are located in an enclosure within the vault. For a below ground vault, the controls are located in an enclosure mounted above ground and communication

wires connect it to the devices located within the vault.

[0181] FIG. 27 shows another embodiment of a local control module 2610 that has the basic complement of features shown in FIG. 26 and in addition, the optional feature of controlling an irrigation system 2710. In some embodiments, the irrigation system can operate according to commands generated by a controller associated with the irrigation system 2710 itself, and, using bi-directional communication channel 2718, can communicate information such as an on or off state 2712, whether it is operating when the aeration system is configured in one of partial vacuum operation or air pressure operation, and commanded to begin operation at an optional preset start time 2716. In other embodiments, the irrigation system 2710 can be commanded, using bi-directional communication channel 2718, to turn on and off 2712, commanded 2714 to operate when the aeration system is configured in one of partial vacuum operation or air pressure operation, and commanded 2716 to begin operation at an optional preset start time. In some embodiments, the system can include logic to operate the irrigation system 2710 to deliberately increase a moisture content of the soil when adding water is appropriate.

[0182] FIG. 28 shows another embodiment of a local control module 2610 that has the basic complement of features shown in FIGS. 26 and 27 and in addition, the feature of using a PDA 2810 to duplicate 2820 all of the control features of the local control module 2610. The PDA 2810 also provides the ability to collect historical operating information 2830, for example for statistical data analysis and for trending analysis.

[0183] FIG. 29 shows a local control module 2610 that has the basic complement of features shown in FIGS. 26 and 27 and in addition, the feature of using a wireless modem 2910 to provide remote two way communication 2920 with the local control module 2610. The wireless modem 2910 provides the ability to control all of the local control modules from a central location 2930, for example using a personal computer situated in a clubhouse of a golf course.

[0184] FIG. 30 is a drawing showing an exemplary embodiment of a user display 3010. In one embodiment, the user display is provided on any or all of a computer monitor, a PDA display screen, and a cellular telephone display screen. In some embodiments, the

display screen is a touch screen. In the embodiment of FIG. 30, the display areas presented to a user include the following: an identifier "GREEN NUMBER" and a display box 3012 in which a number is displayed; an identifier "ENVIRONMENTAL STATUS" with three data identifiers, namely "green temperature," "green moisture," and "ambient temperature," followed respectively by regions 3014, 3016, 3018 in each of which a number is displayed, for example temperature in either degrees Fahrenheit or degrees Celsius, and moisture content as a percentage; a "SELECT MODE" identifier, with three possible modes, identified as "manual," automatic," and "timed," followed respectively by regions 3022, 3024, 3026 that can be "buttons" such as are commonly presented to a user of a computer in a graphical user interface ("GUI") such as Microsoft Windows™, or they can be regions that are activated by a key press or mouse click, so that a user is informed which mode is selected for example by illumination, by color change, by highlighting such as flashing, or by any other convenient visual indication; and at the bottom of the display, three regions comprising "buttons" or indicators, one each for "MANUAL MODE," "TIMED MODE," and "AUTOMATIC MODE." In the event that "manual mode" is selected, the user can turn the motor-blower on or off, by activating a respective one of indicators 3032, 3034, and can select provision of partial vacuum or air pressure during operation by activating a respective one of indicators 3036, 3038. The indicators 3032, 3034, 3036 and 3038 can be regions similar to the regions 3022, 3024 and 3026. In the event that the "timed mode" is selected, numerical indications of time (e.g., in a format such as hours:minutes with or without an AM or PM indication) appear in regions 3042 and 3044, which respectively indicate a time for the controlled motor-blower to start, and a time for the controlled motor-blower to stop operation, as well as indicators 3046 and 3048, which as similar to indictors 3036 and 3038, and which respectively indicate operation with provision of partial vacuum or air pressure. In the event that "automatic mode" is selected, the display indicates a moisture setpoint in region 3052, an ambient temperature setpoint in region 3054, and an optional maximum time of operation in region 3056. The automatic mode when active deals with moisture and temperature excursions from desired values, and can indicate, by activating indicators 3057, 3058, and 3059, whether the automatic system is operating to deal with an excursion in moisture content, an excursion in

temperature, or excursions in both parameters, by activating a respective one of indicators 3057, 358 and 3059. In some embodiment, the display 3010 can further include a logo 3080, a vendor name 3082, and an indication that the system is a "GREENS MANAGEMENT SYSTEM" 3084 (or GMS 3086).

[0185] FIG. 31 is a diagram of an exemplary local control module 2610, showing various control signal paths. The local control module 2610 receives signals from a PDA 3105module indicating the on/off 3112 condition of a motor-blower, the air pressure/partial vacuum configuration 3114of a reversing valve, and a timer on/off time 3116. The local control module 2610 receives information about the condition of an optional irrigation system, including whether the irrigation system is on or off 3122, and whether the irrigation system is configured to operate when the reversing valve is configured to provide air pressure or partial vacuum 3124. The local control module 2610 provides signals indicating the presence of a fault 3130, for example by illuminating a fault light, which can indicate any of the conditions of low batteries 3132, a problem in the battery vault 3134 such as flooding, a motor overload 3136, and a motor underload 3138. A signal 3140 is provided to indicate that the motor-blower is starting (or is operating), and a signal 3150 is provided to indicate the configuration of the reversing valve (e.g., providing air pressure or partial vacuum). The local control module 2610 can in some embodiments receive signals from other hand held controllers, such as cellular telephones. The local control module 2610 can communicate as well with the programmable master control module.

[0186] FIG. 32 is a diagram of an illustrative communication configuration including a local control module (LCM) 2610 and a programmable master control module (PMCM) 3110, and showing various environmental sensor signal paths. In FIG. 32, the local control module 2610 receives a variety of environmental signals from sensors, including humidity 3222, green (or soil) temperature 3224, green (or soil) moisture 3226, ambient temperature 3228, solar radiation level 3230, air flow/air pressure in a conduit 3232, and other signals 3234. The data collected by the local control module 2610 is communicated in one embodiment by wireless communication link 3240 to a programmable master control module 3110.

[0187] FIG. 33 is a diagram showing an exemplary configuration of communication paths including remote access via the Internet. In the embodiment shown in FIG. 33, a local control module 2610 communicates by radio modem with a programmable master control module 3110, which in turn is (optionally) in communication with a remote access site 3310 connected by way of the Internet. The local control module 2610 receives signals 2612, 2614 from a sensor that monitors the current provided to the motor-blower. The local control module 2610 in the embodiment of FIG. 33 controls three subsurface aeration subsystems, and can issue commands to turn motors on and off, and to control a configuration of a reversing valve. The local control module 2610 sends information to a programmable master control module 3110, and receives directives from the programmable master control module 3110. In turn, the programmable master control module 3110 communicates fault conditions 3320, status information such as motor-blower power and/or current 3322 and the like to the remote access site 3310 which is manned by a user. The information sent to the remote access site 3310, which is some embodiments is a personal computer, can be any information that would be displayed to a user on the display screen 3010, as well as other information useful for statistical analysis and trending analysis. The user at the remote access site 3310 can issue commands including, for example, start and stop commands 33 24 for a motor-blower, and configuration commands 3326 to configure a reversing valve to provide a selected one of air under pressure or a partial vacuum. The programmable master control module 3110 in turn issues directives to the local control module 2610, by which directives the local control module 2610 is instructed to carry out the commands of the user operating the remote access site 3310.

[0188] FIG. 34 is an enumeration of some of the components, communication and control channels, and logic structure of one or more embodiments of the golf course environmental management system. The components enumerated include an equipment panel and various field devices. The equipment panel is one example of the local control module described hereinabove. The field devices include a high pressure blower, an air reversing valve and actuator, a sump pump, a float switch, a moisture/soil temperature sensor, and an ambient air temperature sensor, as well as associated operational equipment such as a

local electrical disconnect, a transformer, a motor contactor, a current switch, a motor overload indicator, relays for various purposes, such as starting the motor and operating the actuator for the air reversing valve, a panel door switch and a fault light on the panel door. Some of the field devices are optional in some embodiments. Fig. 34 describes in overview some of the communication and control lines that are provided in some embodiments, and the signals that pass along the communication and control lines. In one embodiment, the description of the communication and control refers to control signals and status signals that are communicated to and from the programmable master control module described hereinabove. The logic requirements, such as blower on based on time of day, or blower on based on temperature and or moisture, can be implemented by local control module itself, or by the programmable master control module (or by a user of the system) and communicated as a directive to the local control module.

[0189] The invention furthermore makes possible a method of decreasing the moisture content of soil in a specific area of interest selected from a plurality of areas of interest within a golf course. The method comprises the steps of providing a subsurface aeration system at each of the plurality of areas of interest, and operating the subsurface aeration system to provide at least a partial vacuum when the soil moisture is greater than a first setpoint value, thereby drawing ambient air through the specific area of interest, causing the partial vacuum to assist in the gravity draining of water from the soil. Each subsurface aeration system comprises a subsurface aeration conduit for providing to the specific area of the golf course at least one of air under pressure and a partial vacuum; an air pump in fluid communication with the subsurface aeration conduit, the air pump configured to provide at least one of air under pressure and a partial vacuum; a motor mechanically connected to the air pump; at least one sensor that measures a soil moisture.

[0190] In one embodiment, the at least one sensor that measures a soil moisture and the at least one sensor that measures a soil temperature are a unitary structure.

[0191] In one embodiment, the method further comprises the steps of providing a control module responsive to a directive, and to the soil moisture, the control module coupled to the subsurface aeration system to control the operation thereof; determining whether the

soil moisture is greater than a first setpoint value, causing the subsurface aeration system to operate to decrease the soil moisture content.

[0192] In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, directing the local control module to operate the subsurface aeration system to decrease the soil moisture content of soil.

[0193] In one embodiment, the method further comprises the steps of providing a programmable master control module in communication with the control module; receiving at the programmable master control module information sent from the control module, the information representing the soil moisture content, comparing it to the first setpoint,; and, if the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem decrease the moisture content of the soil.

[0194] In one embodiment, the method further comprises repeating from time to time the determining step, and while the determination is positive, issuing from the programmable master control module the directive to the local control module to operate the electromechanical subsystem to decrease the moisture content of the soil.

[0195] As should be evident from the disclosure above, systems embodying principles of the invention provide an effective means for treating subsoil regions to maintain the soil temperatures at desired levels. At the same time, the systems can be utilized to promote drainage in these regions as well as providing for subsoil chemical treatment and aeration. The systems can be easily retrofitted to existing golf greens or other similar underground drainage systems or incorporated into new construction.

[0196] Although the present invention has been described with reference to use in association with a four way flow reversing valve, this valve can be replaced by a universal coupling that permits the separator to be selectively coupled to either the discharge or the suction port of the blower. This combined with the use of the above described mobile unit, provides for an economically feasible system for treating existing greens that are in compliance with USGA specifications. Stationary systems embodying the apparatus of the present invention are contained below ground in specially prepared vaults and also located

above ground inside an enclosure and that the local controls associated with the system are automatically operated so that the system is controlled from a remote location without having to enter the vault or enclosure. The principles of the invention can also be applied to California-style drainage systems and to other presently unknown configurations of golf course drainage systems.

[0197] Machine-readable storage media that can be used in the invention include electronic, magnetic and/or optical storage media, such as 3.25 inch magnetic floppy disks and hard disks, a DVD drive, a CD drive that in some embodiments can employ DVD disks, any of CD-ROM disks (i.e., read-only optical storage disks), CD-R disks (i.e., write-once, read-many optical storage disks), and CD-RW disks (i.e., rewriteable optical storage disks); and electronic storage media, such as RAM, ROM, EPROM, Compact Flash cards, PCMCIA cards, or alternatively SD or SDIO memory; and the electronic components (e.g., floppy disk drive, DVD drive, CD/CD-R/CD-RW drive, or Compact Flash/PCMCIA/SD adapter) that accommodate and read from and/or write to the storage media. As is known to those of skill in the machine-readable storage media arts, new media and formats for data storage are continually being devised, and any convenient, commercially available storage medium and corresponding read/write device that may become available in the future is likely to be appropriate for use, especially if it provides any of a greater storage capacity, a higher access speed, a smaller size, and a lower cost per bit of stored information. Well known older machine-readable media are also available for use under certain conditions, such as punched paper tape or cards, magnetic recording on tape or wire, optical or magnetic reading of printed characters (e.g., OCR and magnetically encoded symbols) and such machine-readable symbols as one and two dimensional bar codes.

[0198] Those of ordinary skill will recognize that many functions of electrical and electronic apparatus can be implemented in hardware (for example, hard-wired logic), in software (for example, logic encoded in a program operating on a general purpose processor), and in firmware (for example, logic encoded in a non-volatile memory that is invoked for operation on a processor as required). The present invention contemplates the substitution of one implementation of hardware, firmware and software for another implementation of the

equivalent functionality using a different one of hardware, firmware and software. To the extent that an implementation can be represented mathematically by a transfer function, that is, a specified response is generated at an output terminal for a specific excitation applied to an input terminal of a "black box" exhibiting the transfer function, any implementation of the transfer function, including any combination of hardware, firmware and software implementations of portions or segments of the transfer function, is contemplated herein.

[0199] While the present invention has been explained with reference to the structure disclosed herein, it is not confined to the details set forth and this invention is intended to cover any modifications and changes as may come within the scope and spirit of the following claims.